OFFICE OF CLIMATE CHANGE, SUSTAINABILITY AND RESILIENCY

CITY AND COUNTY OF HONOLULU

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February 12, 2020

The Honorable Ron Menor, Chair
and Members
Committee on Zoning, Planning and Housing
Honolulu City Council
530 South King Street, Room 202
Honolulu, Hawai'i 96813

'20FEB14 PM 2:06 CITY COUNCIL

'20FEB19 PM 3:14 CITY CLERK

Dear Chair Menor and Councilmembers:

SUBJECT: Bill 25 (2019) – Administration EV Readiness and PV Readiness Assumptions and Cost Estimates

The Office of Climate Change, Sustainability and Resiliency ("CCSR") strongly supports passage of Councilmember Elefante's proposed Bill 25 (2019), CD2, which is based on the Administration's proposed bill with additional amendments.[1] Per your request, the Administration submits this letter detailing independent cost estimates and assumptions for Bill 25's electric vehicle (EV) and solar photovoltaic (PV) readiness provisions.

The EV readiness provisions in Bill 25 are an essential building block to ensure that clean and affordable transportation options are available to all of O'ahu residents—not just those that can currently afford it. The American Automobile Association recently published a study recognizing that driving an EV saves 56% per year on fuel and costs $330 less than a gas-powered car to maintain each year.[2] EV's are not only less expensive to maintain and operate than gasoline and diesel fueled cars right now, but they are also projected to be less expensive to buy on an upfront basis within the next five years.[3] Global auto manufacturers are responding strongly to emerging market demands and regulatory mandates for clean and affordable EV options in response to global climate heating. As a result, more EV options are coming to market

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1 See CCSR testimony on the proposed Bill 25 (2019), CD2 here: http://www4.honolulu.gov/docushare/dsweb/Get/Document-250120/MM-015(20).pdf .

2 See https://newsroom.aaa.com/2020/01/aaa-owning-an-electric-vehicle-is-the-cure-for-most-consumer-concerns/

3 Electric cars may be cheaper than their petroleum counterparts by 2025 if the cost of lithium-ion batteries continues to fall. Some models will cost the same as combustion engines as soon as 2024 and become cheaper the following year. See https://www.bloomberg.com/news/articles/2018-03-22/electric-cars-may-be-cheaper-than-gas-guzzlers-in-seven-years or https://www.ucsusa.org/sites/default/files/attach/2017/11/cv-report-ev-savings.pdf

at lower cost.[4] Unfortunately, the lack of readily-available and easily-accessible EV charging infrastructure at residences and workplaces is a significant barrier to current EV adoption, and will hinder attainment of the City and County of Honolulu's renewable transportation goals if not addressed incrementally starting with Bill 25. According to recent polling, 51% of O'ahu residents are likely to switch to a hybrid or EV with 22% of O'ahu residents saying that they are very likely to do so.[5]

The fundamental rationale for EV readiness provisions in the proposed CD2 is that retrofitting existing parking lots and garages to accommodate EV charging infrastructure is cost prohibitive relative to installing EV readiness at the time of new construction. It is estimated that retrofitting EV readiness infrastructure is at least four times more expensive than installing at the time of new construction, and can be as much as ten times or higher in certain other scenarios.[6]

Based on a review and research of available third-party literature and consultation with independent local and national experts in the building design and EV industry, CCSR estimates that installation of Level 2 EV readiness at the time of construction ranges from $459 to $2,900 per stall depending on the type of installation. This estimated range is based on the reports and analysis discussed further below.

A report developed in November 2016 for the Pacific Gas & Electric Company for the City and County of San Francisco ("PG&E Report") estimates per unit costs of $860 and $920 for new construction versus $2,370 and $3,720 for retrofits. As you can read from the attached report and the table below, these estimates cover a 20% EV-readiness level for ten (10) and sixty (60) space parking garages respectively.[7]

Table ES-1. Estimated Cost-Effectiveness of San Francisco Proposal, Two Scenarios

	Per PEV Parking Space with Electrical Circuit		Total Incremental Cost of Building	
	New	Retrofit	New	Retrofit
Scenario A - 10 Parking Space Building, two PEV Parking Spaces	$920	$3,710	$1,840	$7,420
Scenario B - 60 Parking Space Building, 12 PEV Parking Spaces	$860	$2,370	$10,320	$28,440

4 Beyond Tesla, other car manufacturers have announced their commitments to going electric or expanding their electric lineup soon, including Volvo, Ford, Nissan, GM, Volkswagen, Audi, Mercedes-Benz, and Jaguar https://mashable.com/2017/10/03/electric-car-development-plans-ford-gm/#fzOoyJL5aiqu
5 See "Poll: O'ahu Voters Want Action On Climate Change," Nathan Eagle, Honolulu Civil Beat, November 25, 2019 at https://www.civilbeat.org/2019/11/poll-oahu-voters-want-action-on-climate-change/ .
6 See "Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco" prepared for the Pacific Gas & Electric Company (PG&E) by Energy Solutions (Pike et al.), November 17, 2016.
7 *Ibid* p. 1.

The PG&E Report explains the reason for these lower costs:

> "Installing infrastructure during new construction can avoid retrofit costs including breaking and repairing walls, longer raceways (also referred to as conduit) using more expensive methods and upgrading electric service panels. In addition, the soft costs such as permitting and inspections and project management are much lower for new construction."[8]

Essentially, by avoiding labor-intensive elements of EV installation such as trenching, demolition, and re-paving which are necessary under various retrofits,scenarios, the overhead, labor hours, and management complexity of the project are substantially reduced. All elements of the project are simplified and developers can leverage existing work activities that are already occurring during new construction with minimal incremental time and effort. The breakdown of the costs shown in the table below from the PG&E Report illustrates the prior point:[9]

Table 5. Cost Results by Type of Expense

	PEV Circuits Retrofit	PEV Circuits New Construction
Scenario A - 10 Parking Space Building, two PEV Parking Spaces		
Construction Management	$619	$64
Permitting/Inspection	$654	$62
Raceways	$1,065	$178
Excavation	$0	$0
Concrete/Paving	$0	$0
Demolition	$160	$0
Balance of Circuit	$1,214	$613
Total	**$3,713**	**$917**
Scenario B - 60 Parking Space Building, 12 PEV Parking Spaces		
Construction Management	$228	$61
Permitting/Inspection	$207	$27
Raceways	$810	$133
Excavation	$0	$0
Concrete/Paving	$0	$0
Demolition	$140	$0
Balance of Circuit	$1,021	$655
Total	**$2,369**	**$858**

8 PG&E Report, p. 1.
9 *Ibid*, p. 9.

It should be noted that even the ***retrofit*** costs shown above represent a low-end estimate of per unit costs given the lack of excavation and concrete/paving costs.

In addition to the baseline estimates from the PG&E Report, CCSR found additional reports that both corroborate and supplement these estimates by including outdoor curbside and surface parking construction scenarios.

A 2019 analysis of Section 5.106.5.3 of the California Green Building Standards Code (CalGreen) (California Code of Regulations, Title 24, Part 11), estimates costs for EV-capability in non-residential buildings in a range from $739 to $905 per stall for new construction.[10,11]

The table below which shows the difference between new construction and retrofit scenarios for various use cases:

Table ES - 1. Estimated Cost per EV Capable Parking Space, Nonresidential Buildings.

	CALGreen 2019 - 6% of parking spaces		Potential CALGreen 2019 Supplement - 10% of parking spaces		
	Alterations & Additions	Stand-Alone Retrofit	New Construction	Alterations & Additions	Stand-Alone Retrofit
Small Office/ Retail Surface Parking	$1,370 to $1,905	$9,247	$905	$925 to $1,178	$5,540
Medium Office/ School Surface Parking	$912 to $1,516	$4,710	$901	$928 to $1,322	$4,155
Large Office/ Retail/ Hospital Enclosed Parking	$790 to $941	$3,091	$739	$741 to $1,052	$2,779

EV readiness installation costs provided by the Rocky Mountain Institute show average EV Level 2 installation costs for ***retrofits with an EV charger*** in a range from $3,550 to $13,150 per stall depending on whether it is a garage or curbside installation. To estimate ***new construction costs for EV readiness*** from this baseline, since Bill 25 does not require any EV charger installation, we subtract the EV charging equipment

10 See "Plug-In Electric Vehicle Infrastructure Cost Analysis Report for CalGreen Nonresidential Update," prepared for California Electric Transportation Coalition, in partnership with Tesla and Chargepoint, by Energy Solutions, Ed Pike, et al., September 16, 2019, p. 12. https://caletc.com/wp-content/uploads/2019/10/CALGreen-2019-Supplement-Cost-Analysis-Final-1.pdf

11 According to the Hawai'i Chapter of the US GBC; EV-readiness is estimated to cost roughly $100 to $200 than EV-capability due to the extra cost of a 210/240V outlet as a "suitable termination point."

costs and then reduce labor-related costs by 75% to 90%.[12] This reveals a range of EV-readiness cost of $459 to $2,900 per stall and augments CCSR's initial conservative estimates with additional scenarios that may have longer conduit runs and other more costly installation requirements. Therefore, the data indicates that parking garage installations range from $459 to $1,733 per stall and curbside installations range from $580 to $2,900 per stall. See the table below and Appendix A for source data and adjustment calculations.[13]

EV Readiness Cost Estimates Per Stall

	Level 2 Home		Level 2 Parking Garage		Level 2 Curbside	
	Min	Max	Min	Max	Min	Max
Total Retrofit Cost including EVSE (Charger)	$ 650	$ 1,800	$ 3,550	$ 7,500	$ 5,300	$ 13,150
Adjusted for EV-Ready New Construction						
-- Less Charging Station Hardware	$ 150	$ 600	$ 1,800	$ 4,500	$ 3,550	$ 9,650
-- Reduced Labor-related costs - less 90%			$ 459	$ 1,179	$ 580	$ 1,550
-- Reduced Labor-related costs - less 75%			$ 683	$ 1,733	$ 1,075	$ 2,900
Range of Level 2 EV Readiness Costs			**$ 459**			**$ 2,900**

In addition, the points-based EV readiness compliance pathway in the proposed CD2 provides further flexibility for developers and design professionals to comply under differing use cases or scenarios.

Regarding the estimated costs of the solar conduit and PV panel readiness provision, based on channel checks with design professionals through the Hawai'i Chapter of the U.S. Green Building Council and others, the estimated incremental additional cost is minimal and based on the labor and materials cost to install conduit, which ranges from $6.50 to $12.85 per foot. This assumes that the panel upgrade necessary for EV readiness is already installed. In other words, the electrical panel upgrades for EV readiness also accomplish the electrical panel upgrade necessary for PV.

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12 See PG&E Report pgs. 1, 9 and also "Summary of Best Practices in Electric Vehicle Ordinances," by Claire Cooke and Brian Ross, Great Plains Institute, June 2019, p. 8. (https://www.betterenergy.org/wp-content/uploads/2019/06/GPI_EV_Ordinance_Summary_web.pdf

13 For RMI source table see Ohm Home here https://www.ohmhomenow.com/electric-vehicles/ev-charging-station-cost/.

Thank you for the opportunity to provide our cost estimates and assumptions that form the basis of our recommendations related to EV and PV readiness in Bill 25 (2019), CD2 as proposed by Councilmember Elefante.

Should you have any questions, please contact me at (808) 768-2277 or resilientoahu@honolulu.gov.

Sincerely,

Joshua Stanbro
Executive Director and
Chief Resilience Officer

Attachments

APPROVED:

Georgette T. Deemer

Roy K. Amemiya Jr.
Managing Director

Appendix A: EV Readiness Cost Breakdown

		Level 2 Home		Level 2 Parking Garage		Level 2 Curbside		DC Fast Charging		Description/Key Assumptions
		Min	Max	Min	Max	Min	Max	Min	Max	
Charging Station Hardware		$450	$1,000	$1,500	$2,500	$1,500	$3,000	$12,000	$35,000	
Electrician Materials		$50	$150	$210	$510	$150	$300	$300	$600	• $1.50-2.50/ft for conduit and wire, plus misc other materials • $50-80/hr (per dist?)
Electrician Labor		$100	$350	$1,240	$2,940	$800	$1,500	$1,600	$3,000	• $500-1000 if new breaker is required • Assume 2x electrical cost for level 3
Other Materials				$50	$100	$50	$150	$100	$400	• $25-100/ft for trenching/boring- depends on surface, soil, and underground complexity
Other Labor				$250	$750	$2,500	$7,500	$5,000	$15,000	• Mounting, signage, protection and restoration also included here, but don't usually contribute more than a few hundred dollars.
Transformer		N/A	N/A	N/A	N/A	N/A	N/A	$10,000	$25,000	• 480V transformer installed by utility
Mobilization		$50	$200	$250	$500	$250	$500	$600	$1,200	• Home: 1-3 hours of electrician time for a home installation • Public: $250-500 of time for 1-2 electricians and other labor. We found that the work could usually be completed in a single visit from each contractor.
Permitting		$0	$100	$50	$200	$50	$200	$50	$200	• Varies from city to city, often a flat fee for one or several stations
Total Retrofit Cost including EVSE (Charger)		$650	$1,800	$3,550	$7,500	$5,300	$13,150	$29,650	$80,400	
Adjusted for EV-Ready New Construction										
-- Less Charging Station Hardware		$150	$600	$1,800	$4,500	$3,550	$9,650	$17,050	$44,200	
-- Reduced Labor-related costs	90%			$459	$1,179	$580	$1,550	$11,110	$28,000	
-- Reduced Labor-related costs	75%			$683	$1,733	$1,075	$2,900			
Range of Level 2 EV Readiness Costs				$459			$2,900			

Source: RMI sourced through Ohm Home at https://www.ohmhomenow.com/electric-vehicles/ev-charging-station-cost/

ENERGY SOLUTIONS

Pacific Gas and Electric Company®

Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco

November 17, 2016

This report was prepared for the City and County of San Francisco by Energy Solutions on behalf of the PG&E Codes and Standards program.

Prepared by:

Ed Pike, PE
Jeffrey Steuben
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This report was prepared by the California Statewide Investor-Owned Utilities Codes and Standards Program and funded by California utility customers under the auspices of the California Public Utilities Commission.
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ACKNOWLEDGEMENTS

The PEV Infrastructure cost-effectiveness model used for this report leverages prior experience from research funded by the California Energy Commission.

The authors wish to express appreciation to the following reviewers:

Shayna Hirschfield-Gold, City of Oakland

Barry Hooper, City and County of San Francisco

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Executive Summary

This report estimates the costs associated with including Plug-in Electric Vehicle (PEV) charging infrastructure during initial construction for multi-family and nonresidential projects compared to retrofitting this infrastructure at a later date. The City and County of San Francisco is currently considering potential local building codes that would require PEV charging infrastructure as part of new construction and certain renovations.

This report finds that installing PEV charging infrastructure during initial construction is very cost-effective. Table ES-1 below shows that the cost for installing complete or nearly complete 240-volt 40-amp electric circuits as a retrofit is several times more expensive than installing this infrastructure during new construction. Installing infrastructure during new construction can avoid retrofit costs including breaking and repairing walls, longer raceways (also referred to as conduit) using more expensive methods and upgrading electric service panels. In addition, the soft costs such as permitting and inspections and project management are much lower for new construction.

Table ES-1. Estimated Cost-Effectiveness of San Francisco Proposal, Two Scenarios

	Per PEV Parking Space with Electrical Circuit		Total Incremental Cost of Building	
	New	Retrofit	New	Retrofit
Scenario A - 10 Parking Space Building, two PEV Parking Spaces	$920	$3,710	$1,840	$7,420
Scenario B - 60 Parking Space Building, 12 PEV Parking Spaces	$860	$2,370	$10,320	$28,440

The cost estimates in this report are based on the scenarios described below and cost factors from industry reference materials. These cost estimates are not intended to represent the costs of any specific installation and the report does not discuss costs outside of building code compliance. These additional costs can include Electric Vehicle Supply Equipment (EVSE) that plugs into the PEV, associated lighting, signage, any required bollards, etc.

Purpose and Policy Background

The purpose of the Plug-in Electric Vehicle Infrastructure Cost-Effectiveness model and summary report is to document the expected cost-effectiveness of installing PEV charging electric circuit infrastructure during new construction and major alterations of multi-family and nonresidential buildings. A lack of PEV charging infrastructure is a key challenge for meeting California PEV adoption goals as noted in the 2016 California Zero Emission Vehicle (ZEV) Action Plan. This documentation will help local governments such as the City and County of San Francisco and others consider local building code requirements that support PEV charging infrastructure installation to address this challenge. This infrastructure will facilitate PEV adoption and thus also reduce greenhouse gases and other pollutants as well as petroleum dependence.[1]

The California Green Building Code (CALGreen) is formally adopted statewide by the California Building Standards Commission (BSC) for residential and nonresidential buildings and contains statewide minimum PEV charging electrical infrastructure requirements summarized in Table 1. The residential section is authored by the California Department of Housing and Community Development (HCD) and the nonresidential section is authored by the BSC. CALGreen requirements for PEV-ready parking spaces in new construction (Title 24 Part 11 sections 4.106 and 5.106) include sufficient electrical panel capacity and installing raceways through locations that are much easier and more economical to access during construction than as a retrofit.

Table 1. Summary of CALGreen Mandatory and Voluntary PEV Readiness Standards

	Nonresidential				Multi-family dwelling	
	Mandatory		Tier 1	Tier 2		
	Current	Effective Jan. 1, 2017	Effective Jan. 1, 2017		Current Mandatory	Current Voluntary
Minimum threshold	51 parking spaces	10 parking spaces	10 parking spaces	One parking space	17 units	17 units
Percent of new parking spaces that must be EV Ready	3%	~6%[2]	~8%	~10%	3%	5%

CALGreen also contains voluntary model requirements for some sections of the code including PEV charging infrastructure (Title 24 Part 11 sections A4.106 and A5.106). Local governments may choose to adopt the model requirements (or "Tiers") as-is, which then become mandatory in

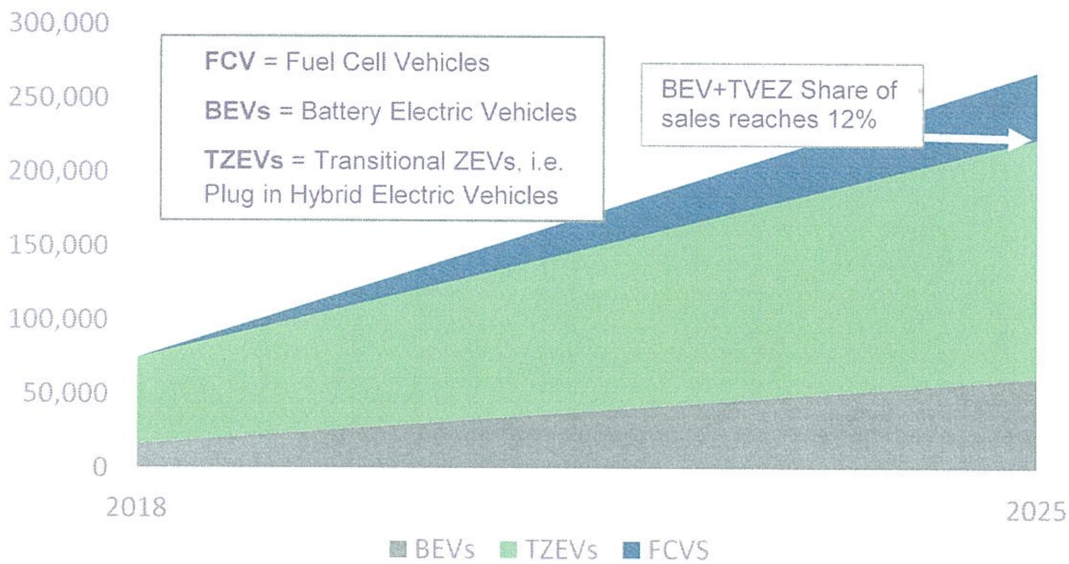
[1] Avoided emissions from displacing a typical vehicle's 15,600 miles annual range with electrically powered miles include 2.6 tons per year of avoided greenhouse gases. This value accounts for upstream emissions from electricity and oil production. Annual mileage is from "Factors Influencing Vehicle Miles Traveled in California: Measurement and Analysis", Kent M. Hymel, 2014. Emissions rates for a conventional vehicle and for a 2012 Nissan Leaf powered on California electricity are from "Calculating Electric Drive Vehicle Greenhouse Gas Emissions", Ed Pike, 2012.

[2] The number of parking spaces that must be PEV-ready are assigned based on total parking spaces in a batch allocation system rather than an exact percentage, so percentages shown here are approximate.

their jurisdiction, or adopt tailored local codes based on specific local findings.

A number of jurisdictions in the Bay Area and beyond have adopted local code or are considering local code adoption because CALGreen minimums are not high enough to meet California PEV deployment goals and expected local demand. California will need to achieve a 12% statewide PEV market share by 2025 to meet the California Air Resources Board Zero Emission Vehicle program target of 1.5 million zero emission vehicles on the road by 2025 as shown in Figure 1.[3] California is already ahead of CARB's expected trajectory to that goal; as of November 2016, there were already more than 250,000 PEVs on the road in California, nearly half of all electric vehicles in use nationally.[4] The current sales rate of approximately 4% exceeds CARB's expected trajectory by about 50%,[5] so 12% may represent a floor with actual PEV market share potentially much higher. In addition, the 2016 ZEV Action Plan notes that upwards of 1,000,000 charge points will likely be needed at homes, workplaces and public locations by 2020. Furthermore, nearly 100% of new passenger vehicles sold in California between 2040 and 2050 must be ZEVs in order to meet the state's long-term climate goals, and similar goals in cities such as San Francisco. Thus, a dramatic increase in PEV charging infrastructure is needed immediately, and to provide flexibility for growth over the life of each new building.

Figure 1. Annual Electric Vehicle Sales Under CARB Most Likely Compliance Pathway[6]



In addition, Bay Area communities such as San Francisco currently have much higher PEV demand than statewide averages, despite challenges such as very limited PEV charging infrastructure in multi-family housing. Figure 2 below shows that the Bay Area forms a PEV

[3] The California fleet consists of 27 million vehicles per the 2013 California Energy Commission draft IPER report page 173, leading to an estimated 5% PEV deployment in 2025 and sales percentages much higher.

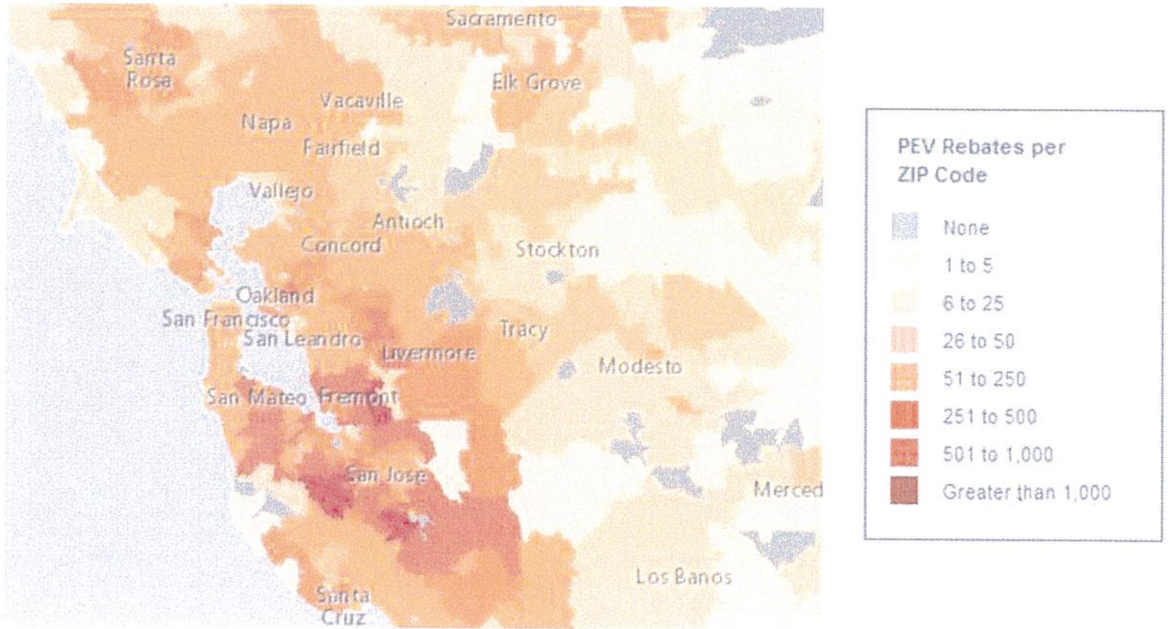
[4] California PEV Collaborative - http://bit.ly/capevcollabnov2016

[5] See CARB "Staff Report: Initial Statement of Reasons for Rulemaking", September 2013, and the Plug in Electric Vehicle Collaborative "Detailed Monthly Sales Chart", April 2016.

[6] This figure is based on CARB's "Staff Report: Initial Statement of Reasons Advanced Clean Cars 2012 Proposed Amendments to the California Zero Emission Vehicle Program Regulations" December 7, 2011.

adoption "hot spot." This figure is based on PEV rebates per zip code. (The number of households per zip code may vary.)

Figure 2: Clean Vehicle Rebate Program Rebate Heat Map by ZIP Code[7]



Building codes can provide significant benefits towards meeting these goals locally due to the considerable potential for new construction in San Francisco. At the time of this report, San Francisco's development pipeline includes more than 71,000 housing units proposed or under construction, and 32 million square feet of new nonresidential uses. While future development trends may vary, this information indicates that adopting local building codes would affect a significant number of future parking spaces.[8]

Building codes will also benefit landlords and tenants. Electric vehicle charging infrastructure is an amenity that can help residential and commercial landlords attract tenants. In addition, the California legislature mandated in 2015 that building owners allow residential tenants in buildings with 6 or more parking spaces to install electric vehicle charging equipment at their own expense upon request. Since the cost of supplying power to an electric vehicle charger is much less when included in new construction, providing electrical infrastructure during original construction will better serve tenants. Thus, building codes will facilitate convenient access to electricity so that residents, commuters, fleets and car sharing services can benefit from the significant operating cost advantages that PEVs provide.

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[7] Downloaded November 15, 2016 from California Clean Vehicle Rebate Program. Please note that not all PEVs sold in California are in the CVRP database, as not every vehicle is eligible and not every owner applies for a rebate.

[8] Totals are calculated from data available in the San Francisco Planning Department Pipeline Report accessed 11-15-2016. While the local code proposal would not apply to units already under construction, developers could voluntarily choose to meet these requirements.

Scenarios

The PEV Infrastructure Cost-Effectiveness model has been adapted from the July 2016 PEV Infrastructure Cost-Effectiveness report developed by Energy Solutions for the City of Oakland. The updated version focuses on the effect of a local code proposal summarized below in Table 2. The City and County of San Francisco is currently considering adoption of this proposal and other jurisdictions are considering similar proposals.

Table 2. Potential Local Building Code Requirements[9]

	Full Circuit	Full Circuit Minus Wire	Inaccessible Raceways	Electric Panel Capacity
Greater than 20 parking spaces	10 percent of parking spaces (rounded up)	10 percent of parking spaces (rounded up)	Install inaccessible raceways at all remaining parking spaces	sufficient to supply 20 percent of spaces at a time (rounded up)
16-20 parking spaces	2 parking spaces	2 parking spaces		sufficient to supply 4 parking spaces
11-15 parking spaces	2 parking spaces	1 parking spaces		sufficient to supply 3 parking spaces
2-10 parking spaces	2 parking spaces	NA		sufficient to supply 2 parking spaces
1 parking space	1 parking space	NA		sufficient to supply 1 parking space

Table 3. Scenario Descriptions

	Scenario A – 10 Parking Spaces	Scenario B – 60 Parking Spaces
Parking Type	one level enclosed garage	two level enclosed garage
PEV Parking Spaces	two	twelve
Base Case Panel	100-amp	two 100-amp
PEV-readiness Panel	200-amp	two 400-amp
Raceway length*	new construction: 40 feet retrofit: 80 feet	new construction: 188 feet retrofit: 360 feet

*Scenario B includes eight feet of raceways for inaccessible locations. The length of raceways for inaccessible locations will vary significantly based on site-specific circumstances.

Two scenarios are included in the model. The first scenario, as summarized in Table 3, is a multi-family or nonresidential building with a ten space enclosed parking area. The electric service panel would be upgraded from 100-amp to 200-amp to support two 240-volt 40-amp circuits. Additional PEV charging infrastructure would include installing in-slab raceways, breakers, an outlet box, and wire to serve two PEV parking spaces. The raceways needed for additional PEV parking spaces could be located in accessible areas and thus would not be required at the time of construction in

[9] Each element is tailored to serve a specific purpose. Full electrical circuits will provide the most convenient solution for installing EVSE. Including some full electric circuits except for wire could provide additional flexibility to support different levels of charging in the future since raceways are typically oversized and thus could potentially support larger wire for faster charging rates. Installation of raceways in locations that are only readily accessible during new construction is a low cost method of enabling future expansion. Some buildings have assigned or deeded parking spaces, reinforcing the benefits of enabling PEV charging infrastructure for each parking space.

this scenario. In both scenarios, raceways installed in the concrete slab during new construction result in more direct routing and shorter lengths, as well as less expensive materials and installation.[10]

The second scenario is a larger building with a two level, 60-space enclosed parking area. Six PEV parking spaces would be served by full 240-volt 40-amp electric circuits and six PEV parking spaces would be served by full electric circuits minus wire. Two 100-amp main circuit breakers (3 wire, 3 pole) would be required to support lighting and other loads in the base case and would be upgraded to two 400-amp panels, one on each level, to achieve support PEV charging infrastructure. Electrical circuits would pass through a six-inch-thick wall. Raceways to support the additional 48 parking spaces would be installed through the electrical room wall (with relatively minimal cost), and additional raceways for these parking spaces could be added in accessible areas as needed.

Modeling for the two scenarios does not include accessibility requirements such as slope, vertical clearance, and path of travel.[11] Local codes that address accessibility at the time of new construction, such as the City and County of San Francisco code proposal, can result in significant cost savings compared to retrofitting parking areas later.

While most parking associated with multi-family and nonresidential buildings in San Francisco is located in enclosed garages, some parking is located in surface lots. The July 2016 PEV Infrastructure Cost-Effectiveness report demonstrates that installing PEV charging infrastructure during new construction is even more cost-effective in the case of surface parking areas than the results shown below for enclosed garages.

Results

The results of the cost-effectiveness analysis for this report show that installing a complete electric circuit for PEV charging during new construction provides major cost savings compared to the cost of retrofitting this equipment. This study estimates that retrofitting installation of full electric circuits for PEV charging at an existing building costs about $2,370-$3,710 per parking space as shown below in Table 4. The same infrastructure would cost about $860-$920 per space if installed during new construction. To determine the cost per parking space, the total incremental cost of increasing PEV charging infrastructure due to the City and County of San Francisco code proposal was divided by the number of PEV parking spaces with complete or nearly complete electrical circuits.

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[10] Some sections of raceways can likely be shared and some will be dedicated to one specific circuit. Half of raceways are assumed to be shared by two wires, with the other half holding a single wire, for Scenario B. The sharing of raceways varies based on infrastructure configuration in Scenario A.

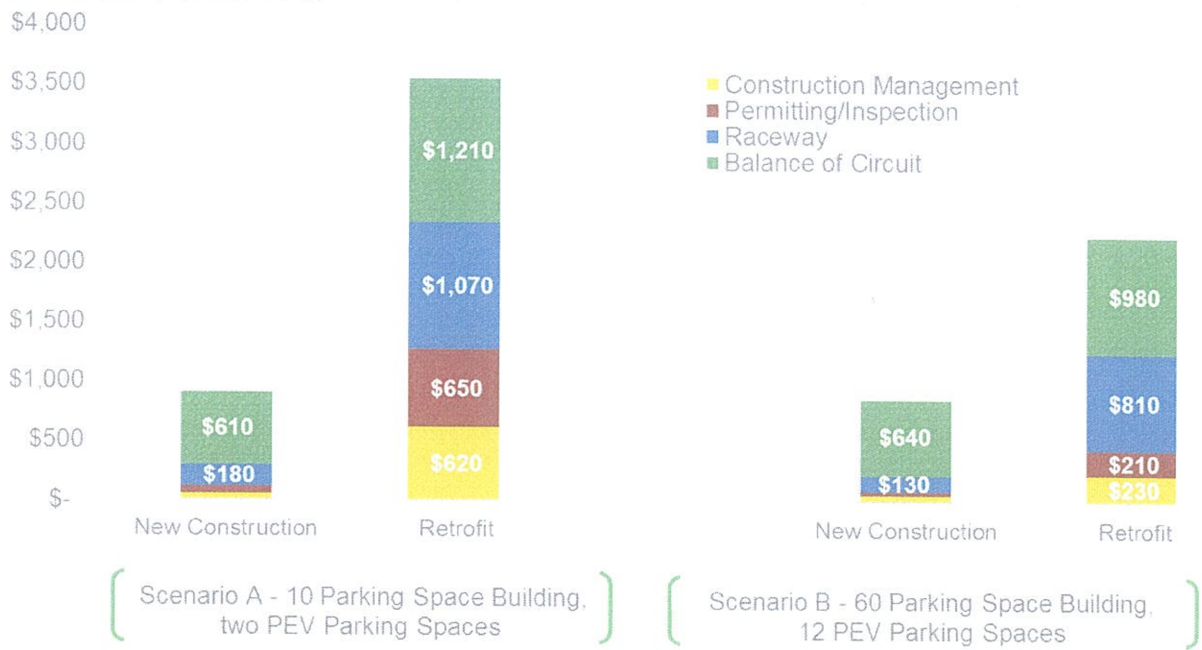
[11] For instance, see Chapter 11B and the residential section of CALGreen. The City and County of San Francisco is considering local code requirements to address these requirements in addition to local code requirements that address electrical charging infrastructure.

Table 4. Estimated Cost-Effectiveness of San Francisco Proposal, Two Scenarios

	Per PEV Parking Space with Electrical Circuit		Total Incremental Cost of Building	
	New	Retrofit	New	Retrofit
Scenario A - 10 Parking Space Building, two PEV Parking Spaces	$920	$3,710	$1,840	$7,420
Scenario B - 60 Parking Space Building, 12 PEV Parking Spaces	$860	$2,370	$10,320	$28,440

Figure 3 below summarizes the major categories of costs, which include breaking and repairing parking lots and sidewalks, upgrading electrical service panels, obtaining permits and inspections, and installing electrical circuits or elements of electric circuits. Permitting and inspection are a common expense for all building types, though higher for retrofits as explained in Appendix B and Appendix C. Electrical panel upgrades will be required in some cases depending on existing panel capacity and PEV charging capacity needs. This analysis is not intended to address every possible site-specific cost. Actual costs for any specific installation will vary due to site-specific conditions.

Figure 3. Relative Cost per PEV Charging Space of PEV Charging Infrastructure in New Construction vs. Retrofits (2016 dollars)



The results indicate that applying PEV-charging infrastructure building codes to building alterations would also provide potential cost savings. For instance, installing underground raceways during parking area expansion or renovation could potentially achieve much or all of the cost savings for conduit installation during new construction. Requiring that new electrical service panels contain capacity for PEV charging could similarly avoid significant costs for retrofitting expanded electrical service later. Data from the Construction Industry Research Board indicates that alterations and additions represent about 21% of the value of permitted construction for both residential and nonresidential new construction statewide.[12] The share of alterations and additions is likely to be higher in San Francisco since most land is already developed, leading to significant potential for PEV charging infrastructure in alterations and additions as well as in new construction as noted earlier.

Methodology

The cost-effectiveness model was developed in Microsoft Excel and utilizes spreadsheets that break each scenario and level of PEV charging infrastructure into individual tasks and quantities, as shown in Appendix C. The model also contains estimates for the costs of each job task. Estimates of retrofit and new construction costs per job task are largely based on RS Means, which is a construction cost reference handbook, for hardware and related installation costs. Additional costs are based on staff estimates for contractor labor for permits and inspections and City and County of San Francisco listed permit and inspection fees. Additional information used in the model includes feedback from industry and utility experts, engineering estimates, and direct experience to capture different tasks required for the scenarios that were analyzed. For additional details on the methodology and information specific to the PEV charging infrastructure details, please see Appendix C.

The cost-effectiveness model includes hypothetical installation scenarios to allow easy comparison of costs between different levels of PEV charging infrastructure for both new construction and retrofit projects. Actual project costs and configurations will vary; thus these cases are intended to provide representative examples for comparison purposes rather than to estimate site-specific costs. PEV charging infrastructure building code requirements can also reduce or avoid non-cost barriers such as coordinating between building owners/operators and tenants, lack of awareness of PEV charging as an option, and the effort of undertaking a construction project in order to be able to fuel a PEV. The modeled costs exclude design work and also other project-specific costs outside the scope of PEV charging infrastructure building code compliance such as signage, lighting, pedestal mounts, bollards, wheel stops, longer raceways, and contingencies.[13]

The model also does not include utility-side infrastructure such as sizing transformer pads and connections to accommodate potential swap-out for a larger capacity transformer.[14] Furthermore, the scenarios also do not include sub-metering or separate metering equipment, which are optional, but could be selected by a building owner to access a special electricity rate.[15]

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[12] "Non-Residential Building Permits By Month", accessed 6-15-2016 and "Residential Building Permits By Month", accessed 6-15-2016.

[13] RS Means specifies a range of potential design costs, while noting that design costs will likely be 50% higher for alterations.

[14] Sizing a transformer pad and connections for a transformer with the capacity to accommodate expected future PEV charging load is a significant source of cost savings, even if a larger transformer is not actually installed until later when required to accommodate PEV load. A report prepared by HCD – "Report on Electric Vehicle Readiness" (November 2013) provides some data on transformer costs.

[15] A sub-meter may be a desirable add-on for some building owners or PEV drivers to allocate electricity costs and/or provide access to utility PEV charging electricity tariffs, though some special electricity rates for PEV owners are available through whole-house rates and utilities are also conducting pilots of metering via electric vehicle service equipment. We believe that builders wishing to install a socket for a sub-meter at the time of new construction may achieve cost savings compared to retrofits but we have not quantified this potential.

Appendix A: Cost Estimates by Type of Expense

The table below summarizes model results per parking space with a complete or nearly complete PEV charging electrical circuit. See Appendix B and Appendix C for more details on the individual tasks included in each of the categories below. The per parking space costs are calculated by dividing the cost per building, including in some cases some small additional cost for PEV-readiness at additional spaces as explained earlier, by the number of PEV parking spaces with complete or nearly complete electrical circuits.[16] The additional cost for PEV-readiness beyond parking spaces with complete or near complete circuits affects only Scenario B and does not affect the results presented below by more than five percent.

The individual expense types for Scenario B reflect a PEV parking space with a full circuit including wire, while the total is slightly different because it is an average of all PEV parking spaces including some without wire.

Table 5. Cost Results by Type of Expense

	PEV Circuits Retrofit	PEV Circuits New Construction
Scenario A - 10 Parking Space Building, two PEV Parking Spaces		
Construction Management	$619	$64
Permitting/Inspection	$654	$62
Raceways	$1,065	$178
Excavation	$0	$0
Concrete/Paving	$0	$0
Demolition	$160	$0
Balance of Circuit	$1,214	$613
Total	**$3,713**	**$917**
Scenario B - 60 Parking Space Building, 12 PEV Parking Spaces		
Construction Management	$228	$61
Permitting/Inspection	$207	$27
Raceways	$810	$133
Excavation	$0	$0
Concrete/Paving	$0	$0
Demolition	$140	$0
Balance of Circuit	$1,021	$655
Total	**$2,369**	**$858**

[16] Half of spaces in Scenario B do not include wire based on the City and County of San Francisco proposal.

Appendix B: Permitting and Inspection Costs

Table 6. Total Permit and Inspection Cost Summary

		Retrofit			New (Incremental Costs)		
Scenario	**# of Circuits**	**Fee**	**Builder Staff Time**	**Total**	**Fee**	**Builder Staff Time**	**Total**
A	2	$ 461	$ 650	$1,111	$ 27	$ 75	$ 102
B	12	$1,365	$ 850	$2,215	$ 164	$ 125	$ 289

Table 7. Electrical and Building Permit and Inspection Cost Data

Electrical and Building Permit and Inspection Cost Data				
Electrical				
Fees				
$335	Minimum inspection fee, which covers from 1 to 3 inspections			
$11	Estimated average application fee per additional circuit beyond minimum			
Builder Time Costs				
Retrofit	New Construction (Incremental Cost)			
$100	$25	Builder staff time to obtain new permit (inclusive of travel)		
$100	$25	Builder staff time per inspection (inclusive of travel)		
$150	$0	Electrical engineer staff time for load calculations		
Building				
Fees				
New Construction		*Alterations*		
Plan	Permitting	Plan	Permitting	
-	-	$ 144.85	$ 62.08	up to $500
-	-	$ 2.93	$ 1.26	per hundred from $500 up to $2000
-	-	$ 1.78	$ 0.76	per hundred from $2000 up to $50,000
$ 0.19	$ 0.10	-	-	per hundred from $5,000,000 to $50m
source: San Francisco Fee Table 1A-A				*note: only costs used in model are listed*
Builder Time Costs				
Retrofit	Incremental Cost, New			
$100	$25	Builder staff time to obtain new permit		
$100	$0	Builder staff time per inspection (inclusive of travel)		

Notes: Fees are calculated based on San Francisco Fee Table 1A-A (building) and Table 1A-E (electrical). New construction fees are based on the incremental cost of adding PEV charging infrastructure to a project. Plan check fee are included for the incremental cost for adding PEV charging infrastructure in new construction (the total project cost would exceed plan check thresholds) and for retrofitting 6 or more spaces. Two building inspections are assumed for retrofits, and no additional building inspections are assumed for new construction. One electrical inspection is assumed for adding two circuits and three are assumed for adding 12 circuits.

Appendix C: Methodology Details

General Assumptions:

- Cost estimates include a fixed general overhead and profit factor.[17]
- Labor costs are based on union labor. The use of union labor will vary from project to project.
- Geographic adjustments are based on 2010 RS Means Electrical Cost Data page 465. Table 8 shows San Francisco adjustments to RS Means national construction costs for labor and materials.
- In a number of cases RS Means contains minimum retrofit task costs.[18] In these cases the lesser of the minimum task cost or the sum of the actual task costs was applied. Where related tasks had separate minimum task costs but the labor crew could likely perform more than one related task, the model applies one minimum labor charge.

Table 8. Regional Factors Compared to National Average[19]

	San Francisco	
	labor	materials
Cost Multiplier	1.44	1.107

Data Sources:

Estimates of retrofit and new construction costs are based on data from RS Means Quarter 3 2013, a construction cost reference handbook and online tool, for hardware and related installation costs; City and County of San Francisco permit and inspection fee sheets; and the authors' estimates for contractor labor for permitting and inspection. Costs were escalated to 2016 using US Bureau of Labor Statistics Producer Price Index statistics for materials[20] and California Director of Industrial Relations labor costs for San Francisco from 2013 to 2016.[21] Additional data sources included feedback from industry experts, engineering estimates and direct experience to capture different tasks required for the scenarios that were analyzed. Table 9 below contains a list of all tasks included in the analysis.

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[17] Individual RS Means line items related to overhead (under General Requirements) are assumed to be addressed by overhead and profit.

[18] Minimum task costs are typically not relevant for new construction due to the overall project scale.

[19] Data is sourced from RS Means Electrical Cost Data 2010 p482. The national average =1.0. The regional factor is also adjusted to account for the faster escalation in San Francisco labor costs from 2013 to 2016 compared to other regions.

[20] Material cost adjustments from 2013 to 2016 are based on the Producer Price Index category 1175 "Switchgear, switchboard and industrial controls" relative index from Nov 2013 to March 2016 which shows virtually no change.

[21] See http://www.dir.ca.gov/OPRL/main.htm for prevailing wage and superseded prevailing wage determinations for electrical job categories.

Soft Costs:

Permit and Inspection Fees

Permitting costs for breaking concrete and electrical permit fees are based on City and County of San Francisco fees in Table 1A-A and Table 1A-E. The total estimated costs include rough and final building and electrical permit fees where applicable. The cost for adding PEV infrastructure tasks to construction of a new building is assumed to be relatively low. Builder staff time for permit filing and inspections are included at $100 per hour spent on site. Permit and inspection costs may vary between regions.

The model includes a small amount of labor to accommodate permitting and inspection of PEV infrastructure-specific elements in new construction because permitting and inspection are already required and minimal additional effort is expected to add PEV charging infrastructure. Please see Appendix B for more details.

Construction Management

The model includes a general overhead rate of 7.5% for both new and retrofit projects.

The model also includes a cost factor to represent additional fixed costs incurred by contractors for retrofit installations prior to project initiation. This additional cost represents contactor time spent on-site and traveling to survey and evaluate existing conditions as well as time spent estimating project costs and preparing bids. The estimated cost is $300 per contractor bid and $600 per successful project.[22] For new construction, these costs likely do not apply or require minimal additional effort to address PEV charging electrical infrastructure.

Raceways, Wire, and Termination Point:

The length of raceways within a given floor are assumed to be half as long in new construction compared to wall and ceiling mounted retrofits with less direct routing. PVC materials are included for raceways installed in new construction compared to more expensive materials and installation methods for retrofits. Additional raceways may be needed between floors, and for inaccessible areas.

Raceways are each assumed to serve 40-amp electric circuits. We note that wire serving higher capacity Level 2 chargers (i.e. up to 19.2 W) could likely be accommodated by the 1 ¼ inch raceways, and if slightly higher size raceways were required the cost differential would be small. Raceways installed in-slab during new construction will in some cases accommodate more and/or higher capacity wires than retrofits that are wall mounted due to additional bends at corners and obstacles at many retrofits. This potential cost savings is site-specific and not included in the model.

We note that actual configurations can vary based on site-specific circumstances. For instance, if a number of PEV parking spaces are located a significant distance from the main electrical panel, a single raceway run to an additional electrical panel closer to PEV parking spaces could be installed with raceways branching from the panel to the planned EVSE location. This configuration would

[22] This estimate assumes that contractors win half of their bids for retrofit projects. The success rate will vary based on specific circumstances. For instance, a sole source contacting mechanism would result in a higher success rate while a contracting mechanism requiring three of more bids would result in a lower success rate. Actual costs will vary from project to project.

most likely save costs in buildings where the reduced length of raceways would exceed additional electric panel costs.

Some sections of raceways can likely be shared and some will be dedicated to one specific circuit. The model is based on an assumption that half of raceways in larger buildings are shared by two wires, with the other half holding a single wire. For the smaller building, a single raceway will carry either one or two wires. The actual ratio of shared raceways vs. raceways dedicated to a specific circuit for any specific installation will vary based on site specific circumstances.

The termination point is assumed to consist of an outlet box with a face plate and no electric vehicle service equipment (i.e. the unit that connects to the vehicle) installed at the time of construction. No additional curbs or bollards are assumed. Local jurisdictions may wish to include anchor points for EVSE near the termination point. While this cost was not included in the model, it should be small.

Task Descriptions:

Task descriptions for each scenario are listed below in Table 9. The table lists tasks with a note to designate where the task applies to retrofits, new construction or both. Tasks are listed with a "0" quantity where they do not apply or are subsumed in cases where minimum job costs are assumed. A negative number indicates the avoidance of smaller electrical panel(s) due to installation of a larger panel.

Table 9. Task Descriptions and Quantities for Scenarios A and B

Task Description	Construction Type[1]	Work Type[2]	Unit[3]	Scenario A PEV Circuit	Scenario A PEV-Ready[4]	Scenario B PEV Circuit	Scenario B PEV-Ready[4]
Structural concrete, in place, minimum labor/equipment charge	R	P	Job	0	0	0	0
Chemical anchoring, for fastener 1-3/4" diameter x 12" embedment, includes epoxy cartridge, excludes layout, drilling & fastener	R	C	Ea.	2	2	12	12
Concrete sawing, concrete slabs, rod reinforced, up to 3" deep	R	D	L.F.	0	0	0	0
Concrete sawing, concrete, existing slab, rod reinforced, for each additional inch of depth over 3"	R	D	L.F.	0	0	0	0
Selective demolition, concrete slab cutting/sawing, minimum labor/equipment charge	R	D	Job	0	0	0	0
Concrete core drilling, core, reinforced concrete slab, 2" diameter, up to 6" thick slab, includes bit, layout and set up	R	D	Ea.	2	2	12	12
Branch meter devices, main circuit breaker, 400 A, electrical demolition, remove, includes circuit breaker	R	D	Ea.	0	0	0	0
Wire, copper, stranded, 600 volt, #8, type THW, in raceway	N	C	C.L.F.	1	0	2.7	0
Wire, copper, stranded, 600 volt, #8, type THW, in raceway	R	C	C.L.F.	1	0	5.4	0
Wire, minimum labor/equipment charge	R	C	Job	0	0	0	0
Outlet boxes, pressed steel, 4" square	R	C	Ea.	2	0	12	0
Outlet boxes, pressed steel, 4" square	N	C	Ea.	2	0	12	0
Outlet boxes, pressed steel, covers, blank, 4" square	R	C	Ea.	2	0	12	0
Outlet boxes, pressed steel, covers, blank, 4" square	N	C	Ea.	2	0	12	0
PVC conduit, schedule 40, 1-1/4" diameter, in concrete slab, includes terminations, fittings and supports	N	R	L.F.	40	0	180	0
PVC conduit, schedule 40, 1-1/4" diameter, in concrete slab, includes terminations, fittings and supports	R	R	L.F.	0	0	0	0
Rigid galvanized steel conduit, 2" diameter, in trench, includes terminations and fittings	R	R	L.F.	0	0	8	8
Rigid galvanized steel conduit, 2" diameter, in trench, includes terminations and fittings	N	R	L.F.	0	0	0	0
Rigid galvanized steel conduit, 1-1/4" diameter, to 15' H, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	N	R	L.F.	0	0	0	0

Table 9. Task Descriptions and Quantities for Scenarios A and B

Task Description	Construction Type[1]	Work Type[2]	Unit[3]	Scenario A PEV Circuit	Scenario A PEV-Ready[4]	Scenario B PEV Circuit	Scenario B PEV-Ready[4]
Rigid galvanized steel conduit, 1" diameter, to 15' H, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	N	R	L.F.	0	0	0	0
Intermediate metal conduit, 1-1/4" diameter, to 15' high, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF[5]	R	R	L.F.	92	0	414	0
Intermediate metal conduit, 1" diameter, to 15' high, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	R	R	L.F.	0	0	0	0
Conduit, to 15' high, minimum labor/equipment charge	R	R	job	0	0	0	0
Load interrupter switch, 2 position, 300 kVA & below w/CLF fuses, 4.8 kV, 600 amp, NEMA 1	B	I	Ea.	0	0	0	0
Cable lugs, for 2 feeders, 4.8 kV or 13.8 kV	B	I	Ea.	0	0	0	0
Transformer, dry-type, 3 phase 480 V primary 120/208 V secondary, 300 kVA	B	I	Ea.	0	0	0	0
Switchboards, distribution section, aluminum bus bars, 4 W, 120/208 or 277/480 V, 1200 amp, excludes breakers	N	I	Ea.	0	0	0	0
Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 100 amp, 12 circuits, includes 20 A 1 pole plug-in breakers (additional to existing)	R	C	Ea.	1	1	0	0
Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 200 amp, 16 circuits, includes 20 A 1 pole plug-in breakers	N	C	Ea.	1	1	0	0
Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 100 amp, 12 circuits, includes 20 A 1 pole plug-in breakers (cost avoided by installing 200 amp panel at time of new construction)	N	C	Ea.	-1	-1	0	0
Circuit breakers, bolt-on, 10 k A I.C., 3 pole, 240 volt, 15 to 60 amp (commercial main breakers may have these pre-installed)	B	C	Ea.	2	0	0	0
Excavating, trench or continuous footing, common earth, 1/2 C.Y. excavator, 1' to 4' deep, excludes sheeting or dewatering	R	E	B.C.Y.	0	0	0	0

Table 9. Task Descriptions and Quantities for Scenarios A and B

Task Description	Construction Type[1]	Work Type[2]	Unit[3]	Scenario A PEV Circuit	Scenario A PEV-Ready[4]	Scenario B PEV Circuit	Scenario B PEV-Ready[4]
Excavating, trench backfill, 1 C.Y. bucket, minimal haul, front end loader, wheel mounted, excludes dewatering	R	E	L.C.Y.	0	0	0	0
Excavating, chain trencher, utility trench, common earth, 40 H.P., 16" wide, 24" deep, operator riding, includes backfill	B	E	L.F.	0	0	0	0
Excavating, chain trencher, utility trench, common earth, includes excavation and backfill, minimum labor/equipment charge	B	E	Job	0	0	0	0
Cycle hauling(wait, load, travel, unload or dump & return) time per cycle, excavated or borrow, loose cubic yards, 20 min load/wait/unload, 12 C.Y. truck, cycle 10 miles, 50 MPH, excludes loading equipment	R	P	L.C.Y.	0	0	0	0
Excavated or borrow, loose cubic yards, small excavation job, 8 C.Y. truck per hour, excludes loading equipment	R	D	Hr.	0	0	0	0
Asphaltic concrete paving, parking lots & driveways, 6" stone base, 2" binder course, 2" topping, no asphalt hauling included	R	P	S.F.	0	0	0	0
Painted pavement markings, acrylic waterborne, white or yellow, 4" wide, less than 3000 L.F.	R	C	L.F.	100	0	600	0
Painted pavement markings, acrylic waterborne, white or yellow, 4" wide, less than 3000 L.F.	N	C	L.F.	100	0	600	0
Add equipment minimum for concrete demo- assume labor minimum subsumed under saw cut minimum	R	D		0	0	0	0
Mobilization or demobilization, dozer, loader, backhoe or excavator, 70 H.P. to 150 H.P., up to 50 miles	R	D		0	0	0	0
Rent, asphalt distributor, trailer mounted, 38 HP diesel 2000 gallon, one day including 4 hours operating cost	R	D		0	0	0	0
Rent mixer power mortar & concrete gas 6 CF, 18 HP, one day including 4 hours operating cost	R	D		0	0	0	0
Rent core drill, electric, 2.5 H.P. 1" to 8" bit diameter, includes hourly operating cost	R	D		1	1	3	3
Rent backhoe-loader 40 to 45 HP 5/8 CY capacity, one day including 4 hours operating cost	R	D		0	0	0	0

Table 9. Task Descriptions and Quantities for Scenarios A and B

Task Description	Construction Type[1]	Work Type[2]	Unit[3]	Scenario A PEV Circuit	Scenario A PEV-Ready[4]	Scenario B PEV Circuit	Scenario B PEV-Ready[4]
Main Circuit breaker, 3 pole 3 wire 100 amp (a negative quantity indicates cost avoided by installing larger capacity unit)	N	C	Ea.	0	0	-2	-2
Main Circuit breaker, 3 pole 3 wire 100 amp	R	C	Ea.	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 225 amp	N	C	Ea.	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 225 amp	R	C	Ea.	0	0	0	0
Main Circuit breaker, 3 pole 3 wire 400 amp	N	C	Ea.	0	0	2	2
Main Circuit breaker, 3 pole 3 wire 400 amp	R	C	Ea.	0	0	2	2

1. Some codes that appear duplicative are retrofit in one case and new construction in another case.
2. Work Type Codes: Circuit including panel and paint (C), Demo (D), Excavate (E), Fee (F), Electric Infrastructure (I), Paving asphalt and concrete (P), Raceways (R).
3. Unit refers to quantity, such as linear foot (LF), hundred linear foot (CFL), square yard (SY), cubic yard (CY).
4. PEV Ready refers to the level of infrastructure required by the CALGreen multi-family codes, and is included to facilitate comparison with the July 2016 PEV Infrastructure Cost-effectiveness report for the City of Oakland.
5. The distance is increased slightly based on cost factors that are not captured in the model.

Energy Solutions

Plug-In Electric Vehicle Infrastructure Cost Analysis Report for CALGreen Nonresidential Update

Prepared For California Electric Transportation Coalition, in partnership with:

Tesla
ChargePoint

From: Ed Pike, Senior Engineer
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Evan Kamei, Project Manager
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Energy Solutions

Date: September 16, 2019

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Executive Summary

Section 5.106.5.3 of the California Green Building Standards Code or "CALGreen" (California Code of Regulations, Title 24, Part 11)[1] currently requires 6 percent of parking spaces in new nonresidential buildings to be Electric Vehicle capable or "EV capable". CALGreen requires that EV capable parking spaces must be equipped with conduit and electrical panel capacity for 40-ampere, 208/240-volt circuit(s) to support the future installation of wiring and electric vehicle supply equipment (EVSE).

This report provides cost analysis data supporting two potential revisions that would increase the number of EV capable spaces throughout California and support California's Zero Emission Vehicle (ZEV) and EV infrastructure deployment goals.

1) The first revision would increase the required number of EV capable parking spaces in new buildings from the current level of 6 percent to 10 percent (this revision would match the percentage in the January 2020 existing multifamily code requirements).
2) The second revision would specifically require the installation of EV capable parking spaces when certain alterations and additions are made to existing nonresidential buildings. Examples of alterations and additions where EV capable parking spaces could be installed include, but are not limited to: repaving parking surfaces; adding new parking spaces; and "gut" rehabilitation of buildings. [2]

These revisions are modeled in the report as though they would be adopted in June or July of 2020 and would take effect July 1, 2021.

This report estimates the costs associated with adding EV capable parking spaces in small, medium, and large nonresidential buildings at the following points in a building's lifetime: 1) new construction; 2) certain alterations and additions; and 3) retrofit projects. The cost analysis modeling results summarized in this report show that installing EV capable parking spaces in stand-alone retrofits is typically 4 to 6 times more expensive compared to installing EV capable parking spaces during new construction or within the alterations and additions scenarios included in the model, as shown in Table ES - 1.[3] Specifically, if EV capable parking spaces are installed during new construction, \$2,040 - \$4,635 per parking space is saved over the retrofit scenario, depending on the building type. If EV capable parking spaces are installed for existing construction during the repaving of parking surfaces, when adding new parking spaces, or during "gut" rehabilitation of building, \$1,727 - \$4,615 is saved over the retrofit scenario, depending on the building type and the type of alteration or addition.

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[1] CALGreen is revised every three years along with the California Title 24 building codes and is also updated every 18 months during an "intervening" cycle.

[2] This report uses the term "repaving" to mean the removal and replacement of parking surfaces. This report uses the term "gut rehabilitation" to mean projects that involve substantial renovations (such as removing interior finishes) and may involve removing much or all of the building interior. These projects often include electrical room renovations; as noted later, one municipality has also adopted a specific trigger for electrical room renovations.

[3] Cost for installing infrastructure currently required by CALGreen (i.e. 6% of spaces) is not presented because it is currently required.

Table ES - 1. Estimated Cost per EV Capable Parking Space, Nonresidential Buildings.

	CALGreen 2019 - 6% of parking spaces		Potential CALGreen 2019 Supplement - 10% of parking spaces		
	Alterations & Additions	Stand-Alone Retrofit	New Construction	Alterations & Additions	Stand-Alone Retrofit
Small Office/ Retail Surface Parking	$1,370 to $1,905	$9,247	$905	$925 to $1,178	$5,540
Medium Office/ School Surface Parking	$912 to $1,516	$4,710	$901	$928 to $1,322	$4,155
Large Office/ Retail/ Hospital Enclosed Parking	$790 to $941	$3,091	$739	$741 to $1,052	$2,779

Thus, CALGreen revisions that (1) increase the number of EV capable spaces installed during new construction and (2) increase the number of EV capable spaces installed during alterations and additions would be significantly less costly than stand-alone retrofits to install EV capable spaces and would reduce the costs of meeting California ZEV and charging infrastructure goals.

Several factors contribute to higher costs for stand-alone retrofits of EV capable parking spaces: demolition and repair of surface parking for surface parking scenarios; breaking and repairing walls; longer conduit runs (also referred to as raceways); and upgrading electric service panels. In addition, the soft costs (such as permits, plans, inspections, and project management) for stand-alone retrofits are much higher because new construction projects and alterations and additions benefit from significant economies of scale for these types of costs. Furthermore, costs for installing a foot of conduit in enclosed parking during new construction and during alterations and additions (especially alterations that replace the parking surface) are much lower.[4] More details on these cost savings are shown below in the Cost Modeling section and in Appendix A.

The cost estimates in this report are based on the scenarios described in the Cost Modeling section (Table 3 contains a number of details). For instance, the alterations and additions for small and medium buildings with surface parking include both repaving existing parking and adding new parking to existing parking areas. Alterations and additions for enclosed parking include both repaving (i.e. replacing the floor) and replacing walls but not the floor. These cost estimates do not include branch circuit wiring to EV capable parking spaces since it is not currently required under CALGreen. They also do not include electric vehicle supply equipment ("EVSE") acquisition and installation costs, nor associated equipment such as signage, mounting pads, lighting, protective bollards/curbing, any on- or off-site transformer upgrades, nor any required accessibility

[4] Conduit installed in concrete slabs during new construction, alterations and additions that replace parking surfaces, or gut rehabs that remove and replace walls, is much less expensive than surface-mounted conduit.

retrofits.[5] These costs may be incurred later when installing EVSE but are not required to make a parking space EV capable.

Table ES – 2 below presents the cost per square foot of building space for installing EV capable parking spaces. Factors that affect the cost per square foot cost include the building size (the main report contains details on building types), the number of EV capable spaces, and the specific project costs. The cost estimates are based on realistic hypothetical examples but are not intended to represent the costs of any specific, real-world EV capable parking space. Actual EV infrastructure projects may cost more or less than the estimates in this report. While costs will vary based on site-specific circumstances, we expect that the proposed CALGreen revisions will yield significant cost savings across a wide range of building types.

Table ES – 2. Estimated Cost of Installing EV Capable Infrastructure per Building Square Foot.

	CALGreen 2019 – 6% of parking spaces		Potential CALGreen 2019 Supplement – 10% of parking spaces		
	Alterations & Additions	Stand-Alone Retrofit	New Construction	Alterations & Additions	Stand-Alone Retrofit
Small Office/Retail Surface Parking (9500 Sq. Ft.)	$0.29 to $0.40	$1.95	$0.38	$0.39 to $0.50	$2.33
Medium Office/School Surface Parking (60,000 Sq. Ft.)	$0.14 to $0.23	$0.71	$0.23	$0.23 to $0.33	$1.04
Large Office/Retail/Hospital Enclosed Parking (358,000 sq. ft.)	$0.05 to $0.06	$0.21	$0.08	$0.08 to $0.12	$0.31

[5] These costs also do not include the cost to retrofit spaces to meet Title 24, Part 2, Chapter 11B accessibility requirements for buildings and spaces subject to Chapter 11B accessibility rules once EV Capable spaces are built out and EVSE are installed. These requirements include, but are not limited to, slope and path of travel. A number of cities including Fremont, Oakland and San Francisco have adopted local codes to ensure that new construction be designed to meet accessibility rules when EVSE are installed.

Background and Purpose

Purpose

Electric vehicle (EV) capable infrastructure is one key topic covered by the current version of the California Green Building Standards Code or "CALGreen" (California Code of Regulations, Title 24, Part 11), which California Building Standards Commission (CBSC) calls "CALGreen 2019." [6] The purpose of this report is to provide cost analysis data to support adoption of revisions to the requirements for EV capable infrastructure in section 5.106.5.3 and definitions related to alterations and additions in Chapter 2 and Chapter 3 of CALGreen as discussed below. These revisions are modeled assuming adoption in June or July 2020 and an effective date of July 1, 2021.

This report focuses on potential changes to 1) increase the percentage of parking spaces in new construction that are EV capable from 6 percent to 10 percent to match CALGreen Chapter 4 multifamily requirements, and 2) require the installation of EV capable parking spaces during certain alterations and additions. The CALGreen nonresidential code currently requires that EV capable parking spaces must be served by conduit and electrical panel capacity for a 40 ampere, 208/240-volt circuit serving the space, but does not require wiring nor EVSE installation and associated expenses (although many local building codes do require wiring for complete circuits, including terminating at receptacles, and these associated costs are minimal).[7]

This report estimates the costs associated with including EV capable parking spaces in small, medium and large offices and other nonresidential buildings during alterations and additions and new construction compared to stand-alone retrofit projects. Examples of alterations and additions where EV capable parking spaces could be installed include replacement of parking surfaces; addition of new parking; and "gut" rehabilitation of buildings.[8]

EV Infrastructure Policy Goals

The increased proliferation of EV charging infrastructure supports many of California's zero-emission vehicle adoption goals, including the objective to deploy 1.5 million zero-emission vehicles and 250,000 publicly available EV charging stations, including 10,000 direct current (DC) fast chargers, by 2025.[9] California also

[6] While some changes to CALGreen will take effect January 1, 2020, the nonresidential EV Infrastructure requirements will not be affected.

[7] Parking spaces with complete EV charging circuits are called "EV Ready" or in some cases "plug and play." We estimate that wiring costs from the electrical panel to the termination would add minimal cost, consistent with our 2016 report for the City and County of San Francisco, assuming that the receptacle is already required by CALGreen.

[8] The report uses the term "repaving" to mean the removal and replacement of parking surfaces and the term "gut rehab" to mean projects that involve substantial renovations such as removing interior finishes and may involve removing much or all of the building interior. Gut rehabs often include electrical room renovations; as noted later, one municipality has also adopted a specific trigger for electrical room renovations.

[9] Former Governor Edmund G. Brown Jr. Executive Order B-16-2012 set the goal of placing 1.5 million zero-emission vehicles on California's roads by 2025. Former Governor Edmund G. Brown's Executive Order B-48-18 set the goal of 250,000 electric vehicle charging stations, including 10,000 DCFC charging stations, by 2025. In addition, the Charge Ahead California Initiative, [SB 1275

has a goal of deploying 5 million ZEVs by 2030, which will require an even larger scale-up of public charging stations in addition to millions of non-public EV charging stations.[10] As of August 2019, California had 4,800 public Level 2 charging station locations and 705 public DC fast charging stations.[11] California must make significant progress quickly, including updating CALGreen requirements, to meet these goals as well as the air-quality and climate-change targets underpinning these goals. Parking spaces at workplaces and other non-residential buildings will be needed to accommodate a vehicle fleet with 18%-24% ZEVs in 2030. The future percentage of ZEVs will require a much higher percentage of parking spaces than the current CALGreen nonresidential code requirement of 6 percent of parking spaces at new buildings needing to be EV capable.[12]

EV charging infrastructure is a critical policy to help California reach its climate and EV adoption goals by providing opportunities at homes and workplaces as well as overcoming the critical challenge of "range anxiety" associated with EV adoption.[13] Additionally, EV charging infrastructure is an amenity that can help landlords attract tenants. Building codes help facilitate convenient access to EV charging so that residents, commuters, fleets, and car sharing services can benefit from the significant operating cost advantages plus the greenhouse gas emission reductions that EVs provide. Furthermore, because EV capable parking spaces can avoid or greatly reduce several types of costs associated with installing EV charging stations, public and private funding can achieve greater number of EV charging stations faster and more efficiently. Thus, increasing the levels of EV capable parking spaces required by CALGreen will lead to significant increases in EV charging infrastructure.

CALGreen Overview

CALGreen is the first mandatory green building standards code in the nation and often serves as a model for other state and local governments across the county. It was originally developed in 2007 by the CBSC to help meet the goals of AB 32 in reducing greenhouse gases to 1990 levels by 2020.[14] Every three years, the CALGreen code is reviewed, revised, and adopted statewide along with other sections of Title 24 for residential and nonresidential buildings. The latest version of the CALGreen code takes effect on January 1, 2020 and is referred to by CBSC as "CALGreen 2019." CBSC also typically issues supplements to sections of CALGreen during an 18-month intervening cycle. They oversee the preparation of building codes by other state agencies for building types such as residential multifamily and single/dual family homes, schools, and hospitals for formal adoption by CBSC. The CBSC will revise CALGreen nonresidential codes during the

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(De León), Chapter 530, Statutes of 2014] set a goal of placing 1 million zero- and near-zero-emission vehicles into service on California's roads by 2023.

[10] Former Governor Edmund G. Brown Jr. Executive Order B-48-18 set the goal of 5 million zero-emission vehicles on California's roads by 2030.

[11] Statistics are from the Alternative Fueling Station Locator (August 2019): https://afdc.energy.gov/stations/#/analyze?region=US-CA&fuel=ELEC&ev_levels=dc_fast&country=US

[12] The California Air Resources Board's EMFAC2017 database estimates that 21.0 million "LDA" (autombiles) and "LDT1" (light duty trucks) will be on the road in 2030. The database also estimates that 6.3 million additional "LDT2" (a second category of light duty trucks) will be on the road, some of which could be used for workplace communiting or other trips to non-residential buildings.

[13] "Range anxiety" refers to concerns about insufficient range and inability to find EV charging stations.

[14] "CALGreen", Department of General Service, https://www.dgs.ca.gov/BSC/Resources/Page-Content/Building-Standards-Commission-Resources-List-Folder/CALGreen

intervening cycle by adopting the CALGreen 2019 Supplement by June or July 2020 with an effective date of July 1, 2021.

During the prior Title 24 code update cycle (effective January 1, 2020), the California Air Resources Board (CARB), CalETC, ChargePoint, Tesla, Energy Solutions, and a coalition of 29 total stakeholders worked with the California Department of Housing and Community Development (the lead agency for writing residential building codes) and the CBSC to expand CALGreen requirements for EV capable infrastructure in multifamily housing. As a result, the code was revised to require the installation of EV capable parking spaces at 10 percent of parking spaces at new multifamily construction instead of 3 percent. The nonresidential CALGreen EV capable infrastructure requirements (California Code of Regulations, Title 24, Part 11 Sections 5.106 and A5.106) and the multifamily requirements (California Code of Regulations, Title 24, Part 11, Sections 4.106 and A4.106) which will take effect January 1, 2020 are shown in Table 1.

Table 1. Summary of Mandatory and Voluntary CALGreen EV Capable Parking Space Standards for New Construction

Type of Requirement	Nonresidential Effective Now			Multifamily Dwelling Effective January 1, 2020		
	Mandatory	Voluntary Tier 1	Voluntary Tier 2	Current Mandatory	Voluntary Tier 1	Voluntary Tier 2
Minimum Threshold for Codes to Apply	10 parking spaces	10 parking spaces	One parking space	None	None	None
Percent of new parking spaces that must be EV Capable	~6%[15]	~8%	~10%	10%	15%	20%

The California Building Standards Code also allows for more restrictive local amendments that are reasonably necessary because of local climatic, geological, or topographical conditions. Currently, two dozen municipalities in California have adopted local building codes that require more parking spaces than CALGreen, and in many cases require "EV ready" spaces with complete wiring. In addition, many others are currently proposing to do so.[16]

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[15] The number of parking spaces that must be EV capable are assigned based on total parking spaces in a batch allocation system rather than an exact percentage, so percentages shown here are approximate. The current percentages took effect July 1, 2018.

[16] Pike, E. et. al. 2018. Driving Plug-in Electric Vehicle Adoption with Green Building Codes, August 17. ACEEE Summer Conference. Examples of agencies that are proposing local codes include Berkeley, Brisbane, San Jose, San Mateo, and a number of others.

Examples of agencies that are proposing local codes include Berkeley, Brisbane, San Jose, San Mateo, and a number of others.

Opportunity to Revise CALGreen for Alterations and Additions and New Construction

The authors of this report recommend two types of revisions to the CALGreen non-residential codes to better accommodate California's policy goals and greatly reduce EV charging infrastructure costs:

1) expanding the EV capable provisions of CALGreen to apply to alterations and additions to existing buildings;
2) increasing the percentage of required EV capable parking spaces for new construction.

First, there are a significant number of alterations and additions to existing buildings that could potentially be addressed through CALGreen. Data from the Construction Industry Research Board indicates that alterations and additions represent about 21 percent of the value of permitted construction for both residential and nonresidential construction statewide.[17]

Neither the current CALGreen code nor the revisions taking effect January 1, 2020 contain a specific requirement for the addition of EV infrastructure during alterations and additions of existing buildings. The definition of "Additions" in CALGreen Chapter 2 (Section 202) addresses "an extension or increase in floor area of an existing building or structure" and does not appear to specifically address parking areas. CALGreen Chapter 3 (Section 301) contains applicability triggers for additions of at least 1,000 square feet or alterations with a permitted value of at least $200,000 that only applies to "the portions of the building being added or altered within the scope of the permitted work." Thus, CALGreen does not clearly address parking areas and changes such as building additional or repaving existing surface parking.

The authors recommend addressing alterations and additions in the 2019 intervening code cycle revisions. A coalition of 29 stakeholders have already recommended addressing alterations and additions in CALGreen and several municipalities have created precedents.[18] For example, the County of Marin and the City of Atlanta require EV charging infrastructure updates when building or repaving on-site parking or when modifying the electrical service panel. Additionally, the City of San Francisco requires adding EV charging infrastructure during gut rehabilitation of medium to large sized buildings and the City of Menlo Park requires adding EV infrastructure for alterations and additions covering more than 10,000 square feet.[19] CALGreen could contain potential triggers based on repaving existing parking; adding parking; "gut rehabs" of existing buildings; and/or upgrades to electrical rooms. Specific revisions are currently under development for potential adoption as part of the CALGreen 2019 Supplement.

Secondly, the authors recommend increasing the percent of new parking spaces that are at least EV capable. Many local jurisdictions have adopted local code requirements that specify significantly higher percentages of spaces that are at least EV capable and research has shown that adopting these higher percentages will significantly increase the amount of EV infrastructure available to meet California's policy goals. All of these recommendations are discussed further below.

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[17] "Non-Residential Building Permits By Month", accessed 6-15-2016 and "Residential Building Permits By Month", accessed 6-15-2016.

[18] Letter to Batjer, M., Marvelli, M., Metclaf, B. Subject: Proposed CALGreen Electric Vehicle Infrastructure Amendments. Letter from 29 stakeholders to 3 agencies. 29 October 2018.

[19] These examples can be found in City of Atlanta Chapter III Append B Section 101.8; Menlo Park Ordinance Number 1049 amending Chapter 12.18; the County of Marin Green Building Program; and the San Francisco Green Building Code.

Cost Modeling

Scenarios

The modeling scenarios were selected to illustrate the cost of installing EV capable parking spaces during three project types representing different stages in a building's lifetime: 1) alterations and additions, 2) new construction, and 3) stand-alone infrastructure retrofit projects.[20] The scenarios include the project types for small, medium and large buildings. Building types were based on example buildings used for Title 24 building code modeling, as shown below in Table 2, and thus have been vetted as representative of buildings potentially covered by Title 24 building codes. The number of parking spaces per square foot is based largely on a study for the City of Sacramento.[21] Table 2 lists the specific occupancy used to determine the number of parking spaces and EV spaces for a specific small, medium, or large building; and the summaries below describe other similar types of occupancies represented by these building examples.

BUILDING TYPES DESCRIPTIONS

Small buildings: The authors selected surface parking lots with 32 spaces to represent small buildings, including both retail and offices, because we expect that most parking for buildings of this type will have surface parking.

Medium buildings: The authors selected surface parking lots with 150 spaces to represent medium buildings, including offices and hospitals. Surface parking was selected because it is a common option for buildings of this size and will provide another example of surface parking in addition to the small building example.

Large buildings: The authors selected enclosed parking with 400 spaces to represent large buildings, including offices, retail, and hospitals. We assume that large buildings will typically have enclosed parking because they are often located in dense urban environments where parking is located either under or above ground due to land constraints.

Table 2. Example Building Types

Occupancy Type	Large Office	Medium Office	Small Retail
Title 24 Modeling Example Building Sq. Ft.	498,589	53,628	9,375
Modeled Building	358,000	60,000	9,500
Ratio of Building Sq. Ft. to Parking Spaces	896	400	300
Parking Spaces	400	150	32
EV Capable Spaces - 2019 CALGreen (6% of total parking)	24	9	2
EV Capable Spaces - Potential CALGreen 2019 Supplement (10% of total spaces)	40	15	4

[20] Costs for the six percent EV infrastructure in new construction was not modeled because it is currently required.

[21] City of Sacramento, Zoning Code Parking Update (LR11-005), 2012. For instance, the authors assumed one parking space per 300 square feet for small retail/office, one parking space per 400 square feet for medium office/schools, and one parking space per 900 square feet for large office/hospital building. In the later case, we assumed that the building was located in a central business district and thus required significantly fewer parking spaces per square foot than other building types.

PROJECT TYPE DESCRIPTIONS:

New Construction: The project type represents a new building or a new parking lot or garage.

Alterations and Additions: This project type includes two sub-options for alterations and additions. The first sub-option addresses the installation of EV capable infrastructure when parking surfaces are removed, such as replacing and repaving outdoor parking or replacing floors for enclosed parking during a gut rehab. In these cases, conduit can be installed in trenches in outdoor parking or tied to rebar before concrete is poured for parking surfaces in enclosed parking.

In the second sub-option, the authors assumed that existing parking surfaces were not removed. For surface parking, we assumed that conduit was routed (in trenches) around existing parking to the new parking areas. For enclosed parking, we addressed gut rehab projects where much of the existing structure is removed, allowing convenient routing of surface-mounted conduit but not installation in the floor.[22] We selected two types of projects under alterations and additions for each building type to get a range of costs for two scenarios that are covered by several local codes and could be covered by CALGreen building codes.

Stand-alone Retrofit: This project type represents retrofits to meet EV capable requirements at existing buildings as a stand-alone project. (We recognize that actual retrofit projects are likely to install wiring branch circuits to create EV ready spaces; we do not expect the inclusion or exclusion of wiring branch circuits to significantly affect the cost-effectiveness ratios in this report.)

[22] This approach may overstate costs to the extent that parking garage walls are replaced, which could allow installation of PVC (plastic) conduit in walls rather than more expensive surface mounted metal conduit.

Table 3. Scenario Descriptions

	Small Retail/Restaurant	Medium Office/School	Large Office/Retail/School/Hospital
Number of Parking Spaces	32 Surface Spaces	150 Surface Spaces	400 Underground Spaces
Circuits	Two (CALGreen 2019) or 4 (Potential CalGreen 2019 Supplement)	9 (CALGreen 2019) or 15 (Potential CalGreen 2019 Supplement)	24 (CALGreen 2019) or 40 (Potential CalGreen 2019 Supplement)
Parking Levels with EV Spaces	One	One	Two
Electrical Panel Type	Single Phase (Three Wire)	Three Phase (Four Wire)	Three Phase (Four Wire)
Electrical Panel Quantities	CALGreen 2019 - one 100A Potential CalGreen 2019 Supplement - one 225A (one 400A added and one 225A avoided for new construction)	CALGreen 2019 - one 225A Potential CalGreen 2019 Supplement - one 400A	First floor - 2019 CALGreen - one 400A panel; Potential CalGreen 2019 Supplement - two 400A Second floor - 2019 and Potential CalGreen 2019 Supplement - one 400A
Electrical Panel Location(s)	Electrical Room	Electrical Room	Electrical Room; except near new parking for addition of parking or new construction
Wire for Branch Circuits (ft)	None per CALGreen	None per CALGreen	None per CALGreen
Conduit for Branch Circuits (ft) - Alterations & Additions/New	52 to 115	124 to 465	331 to 1269
Conduit for Branch Circuits (ft) Stand-Alone Retrofit	78	182 to 345	1133 to 1551
Trenching Required	Yes	Yes	No
Plans, Permit & Inspection	Included	Included	Included
Transformer	N/A	Not Included	Not Included

Results

The results of the cost analysis for this report show that installing EV capable spaces as a stand-alone retrofit is generally four to six times more expensive compared to during new construction and alterations and additions. Costs for these project types are shown in Table 4 per building, in Table 5 per EV capable parking space, and in Table 6 per square foot of building area. These tables summarize more detailed results by expense category that are shown in Figure 2 and Appendix A. The results show a range of costs per EV capable parking space, which is expected given data collected by CARB showing the variability of costs for retrofit projects.[23] The results show a range for alterations and additions costs; the lower estimate is based on projects where the parking surface is removed and the higher cost estimate is based on the addition of parking for surface parking.

Several factors related to building types affect these results:

- Costs per space are generally highest for small buildings with a small number of retrofits for EV capable infrastructure. Smaller projects must divide fixed costs among fewer spaces than larger projects.
- Costs would likely be lower in the alterations and additions case without repaving if surface parking were adjacent to a building and near the electrical room. The modeling inputs assume that these new parking spaces are located farther away from the electrical room than existing parking, which will not always be true.
- Enclosed parking allows surface-mounted conduit, which is less expensive to retrofit than demolishing and repairing surface parking areas.

In addition, several factors related to project type affect these results:

- Installing conduit in new construction or during repaving alterations is much less expensive than retrofitting it later for several reasons. First, demolition, disposal of materials, and repair of surface parking areas is not required. Secondly, conduit can be installed directly underneath parking rather than routing around existing barriers. In addition, less expensive PVC (plastic) conduit can be installed in the parking floor (tied to rebar before concrete is poured) rather than surface mounted later. While wiring of branch circuits is not included in this report, these shorter lengths will also reduce wiring costs.
- Running conduit through existing buildings will likely require demolition of walls, and potentially also through floors.
- Requiring that new electrical service panels contain capacity for EV capable infrastructure can achieve economies of scale and avoid the situation where an electrical room must be expanded to add additional parking. This later cost is not included in the model, and thus, some retrofits for EV capable spaces would be significantly more expensive.
- Compared to stand-alone retrofits, incremental "soft" costs will be substantially lower for new construction and alterations and additions. This is because fixed costs not related to EV capable spaces will already be required for construction and the incremental cost will be much lower.[24]
- Equipment needed for trenching of surface parking will likely already be on-site during new construction and alterations and additions.
- We did not model a separate electrical room upgrade cost for electrical room upgrades for new construction compared to alterations and additions and stand-alone retrofits.

[23] California Air Resources Board, "Electric Vehicle Charging Infrastructure: Green Building Standards (CALGreen) Code Suggested Code Changes for Nonresidential Buildings Technical and Cost Analysis". 2015.

[24] Pike, Ed and Steuben, Jeff. "Plug-In Electric Vehicle Infrastructure, Cost-Effectiveness Report." 2016.

Table 4. Estimated Cost of Installing EV Capable Parking per Building

	CALGreen 2019 - 6% of parking spaces		Potential CALGreen 2019 Supplement - 10% of parking spaces		
	Alterations & Additions	Stand-Alone Retrofit	New Construction	Alterations & Additions	Stand-Alone Retrofit
Small Office/ Retail Surface Parking	$2,740 to $3,810	$18,494	$3,620	$3,700 to $4,710	$22,160
Medium Office/ School Surface Parking	$8,210 to $13,640	$42,390	$13,610	$13,920 to $19,830	$62,320
Large Office/Retail/ Hospital Enclosed Parking	$18,950 to $22,590	$74,180	$29,570	$29,650 to $42,070	$111,150

Table 5. Estimated Cost of Installing EV Capable Parking per EV Capable Parking Space

	CALGreen 2019- 6% of parking spaces		Potential CALGreen 2019 Supplement - 10% of parking spaces		
	Alterations & Additions	Stand-Alone Retrofit	New Construction	Alterations & Additions	Stand-Alone Retrofit
Small Office/ Retail Surface Parking	$1370 to $1905	$9,247	$905	$925 to $1,178	$5,540
Medium Office/ School Surface Parking	$912 to $1,516	$4,710	$907	$928 to $1,322	$4,155
Large Office/ Retail/ Hospital Enclosed Parking	$790 to $941	$3,091	$739	$741 to $1052	$2,779

Table 6. Estimated Cost of Installing EV Capable Parking Spaces per Square Foot of Building Area

	CALGreen 2019 - 6% of parking spaces		Potential CALGreen 2019 Supplement - 10% of parking spaces		
	Alterations & Additions	Stand-Alone Retrofit	New Construction	Alterations & Additions	Stand-Alone Retrofit
Small Office/ Retail Surface Parking (9500 Sq. Ft.)	$0.29 to $0.40	$1.95	$0.38	$0.39 to $0.50	$2.33
Medium Office/ School Surface Parking (60,000 Sq. Ft.)	$0.14 to $0.23	$0.71	$0.23	$0.23 to $0.33	$1.04
Large Office/Retail/ Hospital Enclosed Parking (358,000 Sq. Ft.)	$0.05 to $0.06	$0.21	$0.08	$0.08 to $0.12	$0.31

Figure 1, Figure 2, and Figure 3 summarize the major categories of costs such as: demolishing and repairing parking lots and sidewalks; upgrading electrical service panels; obtaining permits and inspections; and installing conduit and electrical circuits or elements of electric circuits. Tables showing the specific dollar amounts and percent of total project cost by category are shown in Appendix A.

Figure 1. Cost Break-Down per EV Capable Parking Space – Small Retail/ Commercial[25]

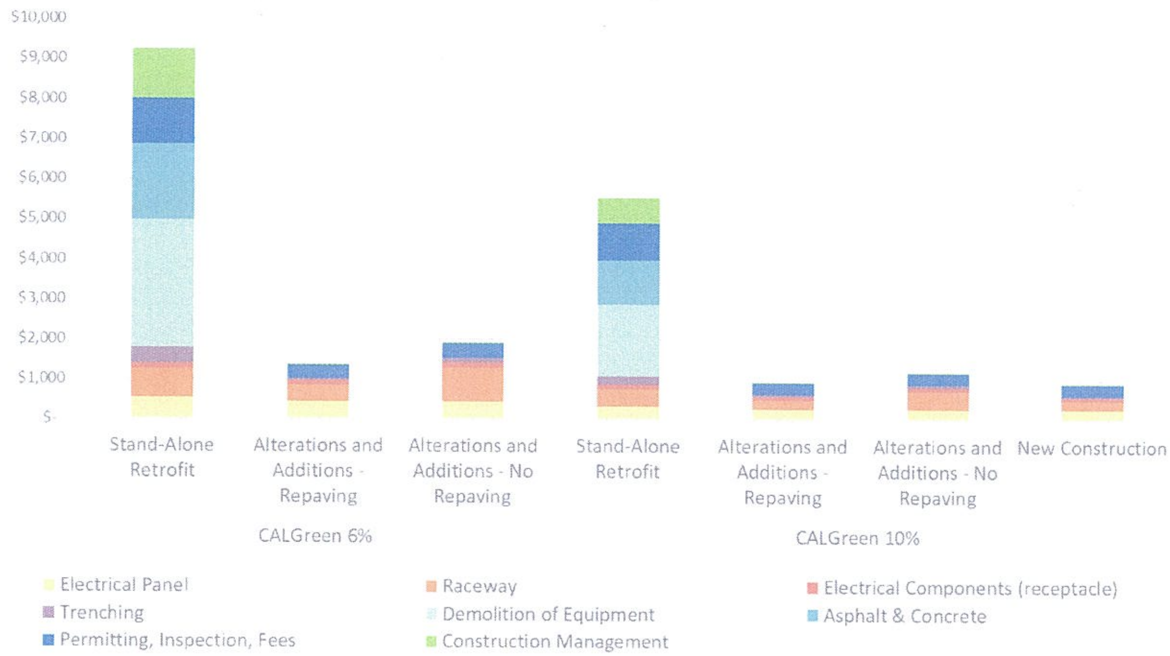
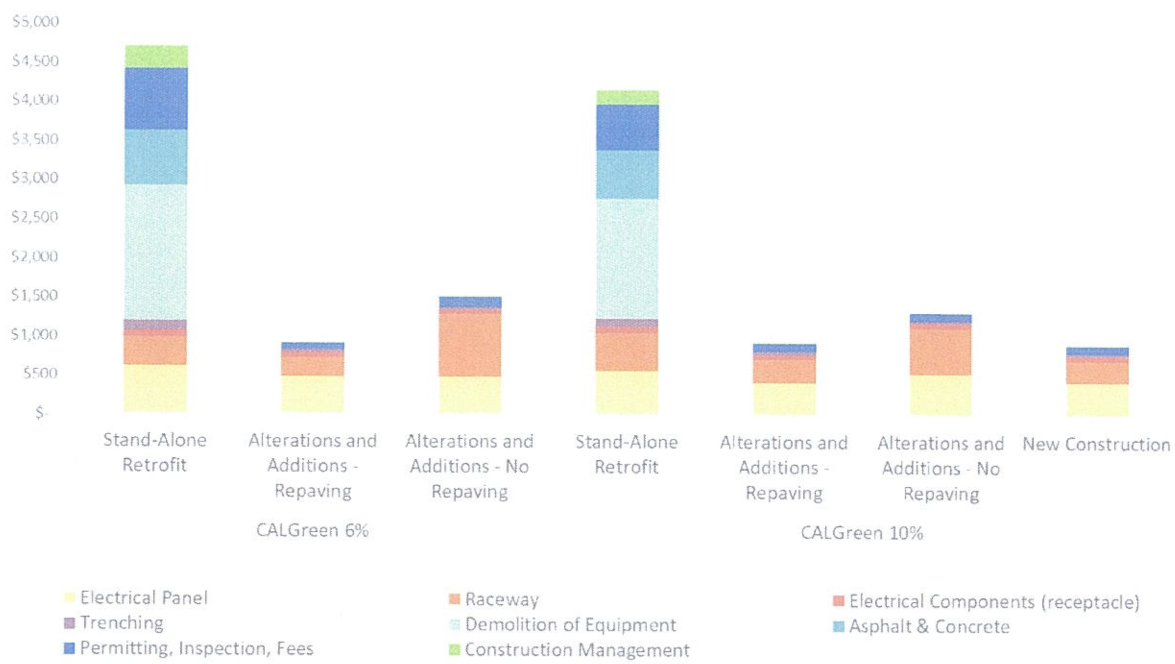
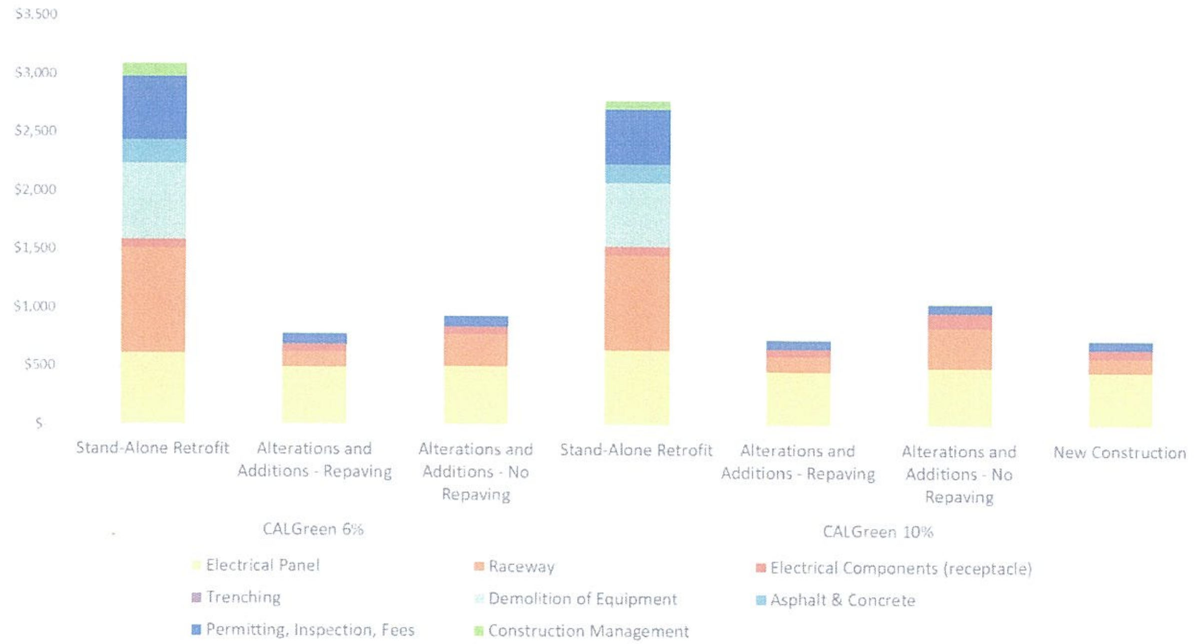


Figure 2. Cost Break-Down per EV Capable Parking Space - Medium Office/ School



[25] For detailed explanations of the different scenarios modeled, see the Scenarios section above. For a high level breakdown of costs, see Appendix A and for a more detailed breakdown of each task included in the costs, see the Task Descriptions section.

Figure 3. Cost Break-Down per EV Capable Parking Space – Large Office/ Retail/ Hospital



Building code requirements for EV capable parking spaces can also reduce or avoid non-cost barriers such as coordinating between building owners/operators and tenants; lack of awareness of EV charging as an option; and the additional time and expense of undertaking a stand-alone EV charging infrastructure construction project. This study does not include accessibility requirements such as slope, vertical clearance, and path of travel. Thus, this study does not capture all the benefits of building code requirements for EV capable parking spaces.

GOOD DESIGN PRACTICES

Several local jurisdictions have adopted building codes that require good design practices to facilitate compliance with accessibility requirements for buildings subject to California Code of Regulations Title 24, Part 2, Chapter 11B Section 11B-812. Section 11B-812 requires that a facility providing Electric Vehicle Charging Stations (EVCS), i.e. a parking space with an EVSE installed, for public and common use also provide one or more accessible EVCS, as specified in Table 11B-228.3.2.1. Chapter 11B applies to certain facilities including, but not limited to, public accommodations and publicly-funded housing (see Part 2, Section 1.9 of the California Building Code). It does not require review prior to construction of whether a building is designed to allow compliance with these requirements, and local codes require good design practices to fill this gap.

These local codes typically require that projects subject to the California Code of Regulations Title 24, Part 2, Chapter 11B, documents how many accessible EVCS would be required as per Title 24, Chapter 11B to convert all required EV capable or EV ready parking spaces to EVCS. They also typically require that the builder demonstrate that the facility is designed such that compliance with accessibility standards, including

Chapter 11B accessible routes, will be feasible for the required accessible EVCS at the time of EVCS installation.[26]

We note that retrofitting spaces which were not designed to facilitate compliance with accessibility requirements can be very expensive. For instance, this study finds that removing and repairing about 100 to 300 linear feet of surface parking that add conduit to non-accessible parking spaces for a small or medium facility can cost $11,500 to $32,000 in demolition and repair costs. While the scope of work for accessibility retrofits may be different from the conduit installation task, this information indicates that the types of costs required for accessibility retrofits (absent good design practices) may be similarly significant.

Methodology

The methodology for this report is similar to prior 2016 reports for the City of Oakland (with funding from the City of Oakland and grant funding from the California Energy Commission), and for the City and County of San Francisco (with funding from Pacific Gas & Electric and in-kind support from the City and County of San Francisco).[27,28]

The cost analysis model was developed in Microsoft Excel and utilizes spreadsheets that break each scenario and number of EV capable parking spaces into individual tasks and quantities, as shown in Appendix C. The model also contains estimates for the costs of each job task. Estimates of retrofit and new construction costs per job task are largely based on RS Means, a construction cost reference handbook for residential and nonresidential hardware and related installation costs.[29] Additional costs for contractor labor, permits, architectural drawings, plans, site and/or load studies (for retrofit projects), inspections, and local permit and inspection fees are based on the resources listed in Appendix B and Appendix C. Additional information used to model these costs includes feedback from industry and utility experts, engineering estimates, and direct experience. For additional details on the methodology and information specific to the EV capable parking space details, please see Appendix C and Appendix D.

The cost analysis model includes hypothetical installation scenarios to compare costs between different numbers of EV capable parking space for new construction and alterations and additions, compared to retrofit projects. Actual project costs and configurations will vary; these cases are intended to provide representative examples for comparison purposes rather than to estimate site-specific costs. The modeled costs exclude project-specific costs outside the scope of EV capable parking space building code compliance such as

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[26] For instance, section 11B-812 requires that "Parking spaces, access aisles and vehicular routes serving them shall provide a vertical clearance of 98 inches (2489 mm) minimum." It also requires that parking spaces and access aisles meet maximum slope requirements of 1 unit vertical in 48 units horizontal (2.083 percent slope) in any direction at the time of new building construction or renovation. Section 11B-812.5 contains accessible route requirements. In addition, Title 24 Part 11 Section 4.106.4.2 requires that developers meet certain aspects of accessibility requirements at the time of new construction for a limited number of parking spaces.

[27] Pike, Ed and Steuben, Jeff. "Plug-In Electric Vehicle Infrastructure, Cost-Effectiveness Report." 2016; and Pike, Ed, Jeffrey Steuben , and Evan Kamei. 2016. "Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco."

[28] Pike, Ed, Jeffrey Steuben , and Evan Kamei. 2016. "Plug-In Electric Vehicle Infrastructure Cost-Effectiveness Report for San Francisco."

[29] For additional information, see www.rsmeans.com.

acquisition and installation of the EVSE, signage, lighting, pedestal mounts, bollards, wheel stops, any required accessibility retrofit, and any other factors outside of CALGreen EV capable parking spaces requirements.[30] (Codes that address accessibility during alterations and additions such as the City of Fremont, City of Oakland City and County of San Francisco local codes can result in significant cost savings compared to changing these design parameters later as part of a stand-alone retrofit project. [31])

The model also excludes utility-side infrastructure such as sizing transformer pads and connections to accommodate potential swap-out for a larger capacity transformer. Furthermore, the scenarios do not include sub-metering or separate metering equipment, which are optional, but could be selected by a building owner to access a special electricity rate.[32] Costs are based on the City of Sacramento rather than the RS Means default of national construction costs because Sacramento will be more representative of California building costs and lie between less expensive (for example Fresno) and more expensive (for example San Francisco) construction markets.

[30] RS Means specifies a range of potential design costs, while noting that design costs will likely be 50 percent higher for alterations. We note that wheel stops may cost $150-$200 each and bollards may cost $500-$750 each based on input from an installer and RS Means costs for equipment types similar to bollards.

[31] San Francisco Green Building Code 2016: http://library.amlegal.com/nxt/gateway.dll/California/sfbuilding/greenbuildingcode2016edition?f=templates$fn=default.htm$3.0$vid=amlegal:sanfrancisco_ca$anc=JD_GreenBuilding

[32] A sub-meter may be a desirable add-on for some building owners or PEV drivers to allocate electricity costs and/or provide access to utility PEV charging electricity tariffs, though some special electricity rates for PEV owners are available through whole-house rates and utilities are also conducting pilots of metering via electric vehicle service equipment. The authors believe that builders wishing to install a socket for a sub-meter at the time of new construction may achieve cost savings compared to retrofits but have not quantified this potential.

Appendix A: Cost Estimates by Type of Expense

The following tables (Table 7 through Table 12) summarize model results for each type of expense per building and combine all costs to provide an average cost per parking space. See Appendix B and Appendix C for more details on the individual tasks included in each of the categories below. The per parking space costs are calculated by dividing the cost of all expenses per building by the number of EV capable parking spaces. The authors did not calculate costs for new construction with CALGreen 6% EV capable parking spaces because that level is required by current building codes.

Labor costs generally range from half to two-thirds of total project costs. Labor costs for small buildings with two EV capable parking spaces, based on current CALGreen 6 percent requirements, were estimated at about four fifths of the total project costs in new construction; however, this may not be representative of other projects for this building type with different site-specific circumstances.

Table 7. Cost by Type of Expense Per EV Capable Space – Small Retail/Commercial[33]

	CALGreen 6%			CALGreen 10%			
	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	New Construction
Electrical Panel	$ 1,065	$ 888	$ 888	$1,319	$ 1,100	$ 1,100	$ 1,100
Raceway	$ 1,443	$ 798	$ 1,682	$ 1,733	$ 886	$ 1,765	$ 886
Electrical Components (receptacle)	$ 307	$ 256	$ 256	$ 460	$ 384	$ 384	$ 384
Trenching	$ 770	$ 79	$ 253	$ 816	$ 137	$ 253	$ 53
Demolition of Equipment	$ 6,350	$ -	$ -	$ 7,136	$ -	$ -	$ -
Asphalt & Concrete	$ 3,812	$ -	$ -	$ 4,452	$ -	$ -	$ -
Balance of Circuit	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Permitting, Inspection, Fees	$ 2,244	$ 704	$ 704	$ 3,726	$ 1,179	$ 1,179	$ 1,179
Construction Management	$ 2,503	$ 15	$ 23	$ 2,520	$ 19	$ 27	$ 18
Total Per Building	$ 18,494	$ 2,740	$ 3,810	$ 22,160	$ 3,700	$ 4,710	$ 3,620
Number of Spaces	2	2	2	4	4	4	4
Cost per EV Capable	$ 9,247	$ 1,370	$ 1,905	$ 5,540	$ 925	$ 1,178	$ 905

[33] For detailed explanations of the different scenarios modeled, see the Scenarios section. For a more detailed breakdown of each task included in the costs, see the Task Descriptions section.

Table 8. Cost by Type of Expense by Percentage – Small Retail/Commercial

	CALGreen 6%			CALGreen 10%			
	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	New Construction
Electrical Panel	6%	32%	23%	6%	30%	23%	30%
Raceway	8%	29%	44%	8%	24%	37%	24%
Electrical Components (receptacle)	2%	9%	7%	2%	10%	8%	11%
Trenching	4%	3%	7%	4%	4%	5%	1%
Demolition of Equipment	34%	0%	0%	32%	0%	0%	0%
Asphalt & Concrete	21%	0%	0%	20%	0%	0%	0%
Balance of Circuit	0%	0%	0%	0%	0%	0%	0%
Permitting, Inspection, Fees	12%	26%	18%	17%	32%	25%	33%
Construction Management	14%	1%	1%	11%	1%	1%	1%
Total Per Building	100%	100%	100%	100%	100%	100%	100%
Number of Spaces	2	2	2	4	4	4	4
Cost per EV Capable	$ 9,247	$ 1,370	$ 1,905	$ 5,540	$ 925	$ 1,178	$ 905

Table 9. Cost by Type of Expense Per EV Capable Space – Medium Office/School

	CALGreen 6%			CALGreen 10%			
	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	New Construction
Electrical Panel	$ 5,569	$ 4,357	$ 4,357	$ 8,477	$ 6,293	$ 7,978	$ 6,486
Raceway	$ 3,352	$ 2,226	$ 7,230	$ 7,269	$ 4,392	$ 8,803	$ 4,107
Electrical Components (receptacle)	$ 691	$ 575	$ 575	$ 1,151	$ 959	$ 959	$ 959
Trenching	$ 1,181	$ 301	$ 203	$ 1,657	$ 619	$ 410	$ 413
Demolition of Equipment	$ 15,537	$ -	$ -	$ 22,966	$ -	$ -	$ -
Asphalt & Concrete	$ 6,312	$ -	$ -	$ 9,223	$ -	$ -	$ -
Balance of Circuit	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Permitting, Inspection, Fees	$ 7,105	$ 697	$ 1,179	$ 8,792	$ 1,560	$ 1,542	$ 1,560
Construction Management	$ 2,645	$ 56	$ 93	$ 2,781	$ 92	$ 136	$ 90
Total Per Building	$ 42,390	$ 8,210	$ 13,640	$ 62,320	$ 13,920	$ 19,830	$ 13,610
Number of Spaces	9	9	9	15	15	15	15
Cost per EV Capable	$ 4,710	$ 912	$ 1,516	$ 4,155	$ 928	$ 1,322	$ 907

Table 10. Cost by Type of Expense by Percentage– Medium Office/School

	CALGreen 6%			CALGreen 10%			
	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	New Construction
Electrical Panel	13%	53%	32%	14%	45%	40%	48%
Raceway	8%	27%	53%	12%	32%	44%	30%
Electrical Components (receptacle)	2%	7%	4%	2%	7%	5%	7%
Trenching	3%	4%	1%	3%	4%	2%	3%
Demolition of Equipment	37%	0%	0%	37%	0%	0%	0%
Asphalt & Concrete	15%	0%	0%	15%	0%	0%	0%
Balance of Circuit	0%	0%	0%	0%	0%	0%	0%
Permitting, Inspection, Fees	17%	8%	9%	14%	11%	8%	11%
Construction Management	6%	1%	1%	4%	1%	1%	1%
Total Per Building	100%	100%	100%	100%	100%	100%	100%
Number of Spaces	9	9	9	15	15	15	15
Cost per EV Capable	$ 4,710	$ 912	$ 1,516	$ 4,155	$ 928	$ 1,322	$ 907

Table 11. Cost by Type of Expense Per EV Capable Space – Large Office/Retail/Hospital

	CALGreen 6%			CALGreen 10%			
	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	New Construction
Electrical Panel	$ 14,842	$ 12,060	$ 12,137	$ 25,879	$ 18,505	$ 19,939	$ 18,467
Raceway	$ 21,418	$ 3,016	$ 6,549	$ 32,429	$ 5,193	$ 13,852	$ 5,155
Electrical Components (receptacle)	$ 1,842	$ 1,535	$ 1,535	$ 3,069	$ 2,558	$ 4,796	$ 2,558
Trenching	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Demolition of Equipment	$ 15,601	$ -	$ -	$ 21,711	$ -	$ -	$ -
Asphalt & Concrete	$ 4,713	$ -	$ -	$ 6,392	$ -	$ -	$ -
Balance of Circuit	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Permitting, Inspection, Fees	$ 13,085	$ 2,217	$ 2,217	$ 18,602	$ 3,193	$ 3,193	$ 3,193
Construction Management	$ 2,677	$ 125	$ 152	$ 3,071	$ 197	$ 289	$ 196
Total Per Building	$ 74,180	$ 18,950	$ 22,590	$ 111,150	$ 29,650	$ 42,070	$ 29,570
Number of Spaces	24	24	24	40	40	40	40
Cost per EV Capable	$ 3,091	$ 790	$ 941	$ 2,779	$ 741	$ 1,052	$ 739

Table 12. Cost by Type of Expense by Percentage – Large Office/Retail/Hospital

	CALGreen 6%			CALGreen 10%			
	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	Stand-Alone Retrofit	Alterations & Additions *Repaving*	Alterations & Additions *No Repaving*	New Construction
Electrical Panel	20%	64%	54%	23%	62%	47%	62%
Raceway	29%	16%	29%	29%	18%	33%	17%
Electrical Components (receptacle)	2%	8%	7%	3%	9%	11%	9%
Trenching	0%	0%	0%	0%	0%	0%	0%
Demolition of Equipment	21%	0%	0%	20%	0%	0%	0%
Asphalt & Concrete	6%	0%	0%	6%	0%	0%	0%
Balance of Circuit	0%	0%	0%	0%	0%	0%	0%
Permitting, Inspection, Fees	18%	12%	10%	17%	11%	8%	11%
Construction Management	4%	1%	1%	3%	1%	1%	1%
Total Per Building	100%	100%	100%	100%	100%	100%	100%
Number of Spaces	24	24	24	40	40	40	40
Cost per EV Capable	$ 3,091	$ 790	$ 941	$ 2,779	$ 741	$ 1,052	$ 739

Appendix B: Permitting and Inspection Costs

Table 13 shows examples of permitting and inspection fees. These fees are not calculated in the model per project but as inputs based on the closest representative level for a project. Table 14 shows the details for these calculations based on the City and County of San Francisco and costs may vary by region.

Table 13. Examples of Total Permit and Inspection Cost Summary

	Stand-alone Retrofit			New, Alterations/ Additions (Incremental Costs)		
# of Circuits	Fee	Builder Staff Time	Total	Fee	Builder Staff Time	Total
2	$461	$650	$1,111	$27	$75	$102
4	$1,365	$850	$2,215	$164	$125	$289

Table 14. Electrical and Building Permit and Inspection Cost Data

Electrical and Building Permit and Inspection Cost Data					
Electrical					
Fees					
$335	Minimum inspection fee, which covers from 1 to 3 inspections				
$11	Estimated average application fee per additional circuit beyond minimum				
Builder Time Costs					
New Construction, alterations &	Stand-alone Retrofit				
$25	$100	Builder staff time to obtain new permit (inclusive of travel)			
$25	$100	Builder staff time per inspection (inclusive of travel)			
$0	$150	Electrical engineer staff time for load calculations			
Building					
Fees					
New Construction, alterations, additions		*Stand-alone retrofit*			
Plan	Permitting	Plan	Permitting		
-	-	$ 144.85	$ 62.08	up to $500	
-	-	$ 2.93	$ 1.26	per hundred from $500 up to $2000	
-	-	$ 1.78	$ 0.76	per hundred from $2000 up to $50,000	
$ 0.19	$ 0.10	-	-	per hundred from $5,000,000 to $50m	
source: San Francisco Fee Table 1A-A				*note: only costs used in model are listed*	
Builder Time Costs					
Incremental Cost, New	Retrofit				
$25	$100	Builder staff time to obtain new permit			
$0	$100	Builder staff time per inspection (inclusive of travel)			

Notes:

- Fees are calculated based on San Francisco Fee Table 1A-A (building) and Table 1A-E (electrical). New construction fees are based on the incremental cost of adding EV charging infrastructure to a project.
- Two building inspections are assumed for small retrofits, and no additional building inspections are assumed for new construction. One electrical inspection is assumed for adding two circuits and three are assumed for adding 12 circuits.

Appendix C: Methodology Details

This appendix provides additional details on the general assumptions used in the models, data sources for per unit equipment and other costs, and the methods used to determine the quantities needed for each expense type. This appendix does not contain data specific to the scenarios that were modeled, but rather a more general overview of the cost model.

General Assumptions

- Cost estimates include a fixed general overhead and profit factor.[34]
- Labor costs are based on union labor, which is higher than non-union labor. The use of union labor will vary from project to project.
- In some cases, RS Means contains minimum retrofit task costs.[35] Where related tasks had separate minimum task costs, but the labor crew could likely perform more than one related task, the model applied one minimum labor charge.

Data Sources

Estimates of per unit equipment and installation costs were based on retrofit and new construction costs from RS Means, a construction cost reference handbook and online tool for hardware and related installation costs. The City and County of San Francisco rates were used for permit and inspection fee sheets; and the authors estimated costs for contractor labor for permitting, inspections, site inspection, and architectural plans. Cost data from RS Means was for 2018 and was scaled to 2019 using U.S. Bureau of Labor Statistics Producer Price Index statistics. Additional data sources include: feedback from industry experts, engineering estimates, and direct experience to capture different tasks required for the scenarios that were analyzed. This appendix contains a list of all tasks included in the analysis.

Soft Costs

PERMIT AND INSPECTION FEES

Permitting costs for breaking concrete and electrical permit fees are based on City and County of San Francisco fees.[36] The total estimated costs include rough and final building and electrical permit fees where applicable. The cost for adding EV capable spaces during construction of a new building is assumed to be relatively low. Builder time spent towards permit filing and inspections is included at $100 per hour spent on site. Permit and inspection costs can vary between regions.

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[34] Individual RS Means line items related to overhead (under General Requirements) are assumed to be addressed by overhead and profit.

[35] Minimum task costs are typically not relevant for new construction due to the overall project scale.

[36] See Table 1A-A and Table 1A-E

The model includes a small amount of labor to accommodate permitting and inspection of elements specific to EV capable parking spaces in new construction and alterations and additions, since these activities are already required, and minimal additional effort should be needed to add EV capable infrastructure.

Since economies of scale occur with larger quantities, these fees generally scale up with increasing quantities of EV capable infrastructure, though they are not completely scalable. Costs are higher for outdoor circuits than for indoor circuits due to trenching and are higher for retrofits than for new construction or alterations and additions due to demolition, repaving, and repairs.[37]

ARCHITECTURAL PLAN FEES

Costs to add EV capable parking spaces to architectural plans and drawings will vary between projects based on their overall complexity. They are based on the estimated number of hours for each project and a fee of $150/hour before geographic adjustments. Costs will also vary if the project is new construction or a retrofit. In the former case, costs will be relatively minor because the architectural firm will likely be familiar with the plan of the building and can easily influence relevant design decisions like adding EV capable infrastructure. For retrofit projects, costs will likely be significantly higher due to the need to investigate and accommodate more complex on-site conditions such as: longer conduit runs, demolition and reconstruction, meeting accessibility requirements based on existing conditions, and/or more limited options for electrical room and panel placement.

A minimal incremental cost is required for adding several EV capable parking spaces to a new building or alteration and addition. In contrast, preparing construction plans for large numbers of EV capable parking spaces to an existing building may take a significant amount of time considering the layout and construction details for each parking space and existing site conditions. Costs will partially scale by the number of EV capable parking spaces.

LOAD STUDY/SITE CONDITIONS STUDY

Additional expenses are required for stand-alone retrofits at medium or large buildings to assess existing load and other conditions. The load study is necessary to determine the current electrical supply capacity, such as the transformer and other systems related to the main electrical supply and the current actual load.[38] The study will then determine which on-site upgrades may be needed to install EV capable parking spaces. In addition, site-specific conditions may need to be determined such as current concrete conditions, soils conditions, and/ or other conditions. A load study at a facility where other site condition studies aren't needed is assumed to cost $1,000. Factors such as demolition and/or a greater number of EV parking spaces will drive costs up and a more complex study is assumed to cost $5,000 in this report (prior to prime contractor expenses). X-ray costs are roughly $1,000 for a half dozen images, which may be enough for retrofit installations at a medium

[37] We note that efforts are underway to streamline permitting and inspections of EV charging infrastructure including EV capable parking spaces.

[38] Transformers are usually sized based on the typical maximum actual load of a building. Unlike electrical panels and electrical circuits, transformers can be under loaded to extend their lifetime of fully loading, or even occassionaly overloaded without causing an immediate reliability issue but with potential reduced long-term lifetime.

sized facility, however, more may be required for a 150-space garage.[39] A specific site may require more or less resources depending on actual conditions.

Assuming alterations and additions originally intended for non-EV charging purposes will require an assessment of load and existing conditions, the assessment would also suffice for EV charging as well.

ELECTRICAL PANEL LOCATIONS AND SIZING

Some electrical panels are located in the main electrical room while others are distributed closer to EV parking spaces to reduce branch circuit lengths and costs. Distributed panels are more practical in locations with convenient wall mounting locations protected from weather and vandalism. All panel and sub-panel conduits are assumed to be installed in 1 ½ inch steel surface-mounted conduits for 225 ampere panels (to carry 250 MCM wire) or 2-inch conduits for 400 ampere panels (to carry 600 MCM wire) to provide a high level of protection and allow for easy visual inspection.

In some cases, a panel installed in new construction can be upsized to serve both base loads (such as garage lighting, elevators, and miscellaneous outlets) and EV charging loads. In other cases, panels for EV charging are sized to their maximum practical size (typically 400 amperes) just to meet EV charging needs. (Panels are generally limited by electrical panel capacity rather than physical size for EV electrical infrastructure. A single-phase 400-ampere panel has electrical capacity for 10 circuits and typically has physical space for 15 40-amperes circuits even if they utilize double slot 20-ampere breakers.)

The type of electrical panels will depend on whether a building is served by three-phase (4-wire) electrical service or one-phase (3-wire) electrical service. Medium and large commercial buildings and multifamily buildings usually receive three-phase service. When a panel receives three phases of electricity instead of one, it can accommodate additional EV capable parking spaces. However, the phases must be "balanced", which restricts how many additional circuits for EV capable parking spaces can be accommodated. We assumed that three-phase 225 ampere panels can accommodate 9 40-amp circuits and three-phase 400 ampere panels can accommodate 15 40 ampere circuits based on interviews with contractors and an electrical design firm.

CONSTRUCTION MANAGEMENT

The model also includes a cost factor to represent additional fixed costs incurred by contractors for retrofit installations prior to project initiation. These costs include contractor time spent traveling to a site for surveying, evaluating existing conditions, estimating project costs, and preparing bids. Costs will vary based on the complexity of the project.[40] For new construction, these costs likely do not apply or require minimal additional effort to address EV capable electrical infrastructure. The construction management category also includes general permit application fees.

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[39] Concrete X- Ray Imaging, Penhall, https://www.penhall.com/concrete-x-ray-imaging/ accessed 7-4-2019.

[40] This estimate assumes that contractors win some of their bids for retrofit projects. The success rate will vary based on specific circumstances. For instance, a sole source contacting mechanism would result in a higher success rate while a contracting mechanism requiring three or more bids would result in a lower success rate. Actual costs will vary from project to project.

Raceways, Wire, and Termination Point

PVC materials (i.e. plastic) are included for branch circuit conduits installed in new construction of enclosed parking areas and alterations and additions to enclosed parking that remove the parking surface, while wall and ceiling-mounted metal conduit is assumed for stand-alone retrofits. The authors assumed that intermediate metal conduit was installed for any outdoor raceway in trenches to provide corrosion resistance and for any indoor retrofit cases where walls and floors will not be replaced. Additional raceways may be needed between floors and inaccessible areas.

One and a quarter-inch raceways are generally assumed to carry up to twelve #8 wires rated at 40 amperes (three per circuit) to support 30-ampere EVSE, with the potential to add wiring for a fifth circuit where convenient.[41,42] Some additional raceways are also needed to serve individual termination locations (i.e. a main conduit run carrying four wires may end at one receptacle pair and a local distribution conduit would carry the other pair to its termination point). These short distribution raceways were also sized at one and a quarter inches for simplicity; though they could be sized at one inch or below, we do not expect that this difference would be significant. In some cases, raceways installed in-slab during new construction will accommodate more and/or higher capacity wires than retrofits that are wall mounted and encounter additional bends at corners and obstacles, limiting their capacity. These potential cost savings are site-specific and not included in the model. Wire is not included for branch circuits for EV capable parking spaces. Wires for any distributed panels that are noted in the scenario summary table are included in the costs.

The length of raceways within a given floor for enclosed parking at new construction and repaving are calculated based on direct routes from the electrical panel to the termination point since no obstacles are present during new construction. Retrofitting surface-mounted conduit is generally assumed to be twice as long in new construction because they must follow walls and ceilings with less direct routing. Compared to new construction, raceway distances are increased by 125 percent for gut rehabilitation because significant portions of the building are removed while some obstructions may remain. Raceway distances are also increased by 150 percent for stand-alone retrofits in outdoor trenches to account for indirect routing (i.e. avoiding existing infrastructure). Surface mounted retrofit distances are increased by 200 percent, compared to new construction, due to the long distances to follow existing walls and to account for routing around existing obstacles.

Actual configurations can vary based on site-specific circumstances. For instance, if several EV parking spaces are located a significant distance from the main electrical panel, a single (larger) raceway run to an additional electrical panel closer to EV parking spaces can be installed with raceways branching from the panel to the planned EVSE location. This configuration would most likely save costs in buildings where the reduced length of raceways would exceed additional electric panel costs. Raceways for electrical panels outside of the main electrical room are sized (at ½ inch intervals, i.e. 1 ½ inch or 2 inches) based on the wire needed to serve that panel.

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[41] Because EV charging is considered a continuous load, the circuit capacity must be at least 25 percent higher than the end load.

[42] We note that higher capacity #6 wire could also be installed at a rate of four sets per 1 ¼ inch conduit without larger sized conduit, unless conduit capacity is limited due to bends that restrict fill rates. For an example of allowable fill rates, see Elliot Electric Supply "Conduit Fill Table" at https://www.elliottelectric.com/StaticPages/ElectricalReferences/ElectricalTables/Conduit_Fill_Table.aspx.

Conduits will generally terminate at a receptacle with an outlet box with a face plate and no EVSE (i.e. the unit that connects to the vehicle) installed at the time of construction. Local municipal building codes can also require a specific type of receptacle, which does not have a large impact on the cost-effectiveness of code. Receptacles are assumed to be installed in pairs to serve parking spaces on either side of the pair.

No additional curbs or bollards are assumed at the termination point. Local jurisdictions may wish to include a requirement for anchor points for EVSE near the termination point if the EVSE can be wall-mounted, which should not significantly affect the cost of EV capable building codes.

Demolition, Reconstruction, and Repaving

The model contains several job types related to demolition, construction, and repaving for stand-alone projects and projects where parking areas and/or electrical rooms are undergoing renovations that would allow installation of this equipment without any further demolition and reconstruction.

For both enclosed and surface parking, demolition for electrical rooms includes cutting and/or drilling, breaking large pieces into smaller pieces, minimum equipment/labor costs, loading and disposal. Reconstruction costs include concrete work (cost for pouring slabs is used as a proxy), reinforcing rods, forms, and minimum labor charges.

Demolition for parking areas include cutting a three-foot-wide section of pavement to allow two-foot-wide trenches; backhoe rental to trench, mobilization and operation, and disposal of materials. Some trenching would also be required for adding EV capable parking spaces in new construction, when repaving existing parking or adding parking. In these cases, costs would likely be much lower due to the presence of trenching equipment on-site to meet other project needs unrelated to EV capable parking spaces.

Contingencies

A 20 percent contingency was applied for stand-alone retrofit projects based on RS Means. Contingencies are necessary because specific challenges may not be visible at the start of a stand-alone retrofit project or because existing conditions may be difficult to alter without expanding the scope and cost of a retrofit project - for instance if an electrical room lacks space for additional panel(s) or was originally constructed far from parking spaces. A general contingency was not added for EV capable parking spaces installed as part of a larger retrofit project such as resurfacing or building new parking spaces at an existing site because the conditions will more closely resemble new construction, given their broader scope. In addition, specific cost increases were already included to address higher costs for alterations and additions compared to new construction, such as conservatively assuming that additional parking spaces would be located further from electrical power than existing spaces.

Transformers

As noted earlier, this modeling study does not include any potential costs of adding an on-site transformer capacity to "step down" 480 V service to 208/240 V for buildings connected to 480 V power. CARB has found that EV charging generally represents a relatively small fraction of overall building power demand in multifamily housing with 10% EV capable parking spaces. These transformer upgrades are often not necessary to support EV charging infrastructure for buildings with three-phase power, which is more common in larger buildings, because one of the phases available from the transformer would typically have capacity for Level 2 (i.e. 208/240 volt) EV charging infrastructure. CARB found that an upgrade may be more likely in buildings with single phase power, depending on whether enough power supply is available.[43]

An electrical engineering firm and several contractors were consulted with and confirmed that they have found that levels of EV capable parking spaces proposed for CALGreen typically would not require a transformer upgrade. It was noted that in some cases, a potential off-site utility infrastructure upgrade could be required. In this case, the costs could potentially be paid for by the utility and recovered over time through utility rates paid by the customer.

Alterations and additions of older, existing nonresidential buildings could result in repaving parking areas without renovating their electrical rooms. In these cases, avoiding an electrical system upgrade may be possible due to spare capacity or potential spare capacity of retrofits that include more energy-efficient lighting and other equipment meeting current mandatory California, ENERGY STAR®, and/or federal standards.

We expect that in cases where a transformer upgrade would be required to install EV capable infrastructure, building codes requiring EV capable parking spaces and associated electrical capacity could achieve significant cost savings related to these costs. Stand-alone transformer retrofits could require replacing conduits serving the transformer, replacing the transformer pad or adding a new pad, and adding an additional transformer or upgrading an existing transformer. By comparison, designing the electrical room for adequate capacity would allow the installation of larger sized conduits and/or transformer pads during initial construction at minimal cost. While we have not quantified these costs, the incremental cost of installing a 3" conduit instead of a 2" conduit would be very small compared to breaking existing concrete to install a larger sized conduit later.

DISTRIBUTION & SERVICE LINE UPGRADES

When necessary, the costs of distribution and/or service line upgrades are partially split between the customer and the utility. Customers are responsible for excavation, conduits, and protective structures while utilities are responsible for wiring, metering, and transformers (if necessary). However, utility funding mechanisms can spill over into customer costs anytime the costs exceed the preset "allowance" for a customer.[44] In addition, if load does not materialize, the utility is able to assess additional charges for the difference in expected revenue.

[43] California Air Resources Board. Electric Vehicle (EV) Charging Infrastructure: Multifamily Building Standards. 2018.

[44] Customers have an "allowance" based on their billing history but to fund utility upgrades but if costs are exceeded, they are charged directly to the customer (PG&E Electric Rule 15 & Rule 16). In addition, if the load does not materialize, the utility is allowed to claw-back funds.

Task Descriptions

Task descriptions for each scenario are listed below in Table 15. The table lists tasks with a note to designate where the task applies to retrofits, new construction, or both. A negative number indicates the avoidance of smaller electrical panel(s) due to installation of a larger panel. (Tasks that are listed with a "0" quantity were included as an option in detailed calculations used to determine project task descriptions, but the detailed design calculations resulted in a zero quantity for the specific task).

Table 15. Task Descriptions and Quantities

Task Description	Construction Type	Work Type	Unit	Small Retail/Commercial				Medium Office/School				Large Office/Retail/Hospital			
				6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving
				Quantity for Each Scenario											
Rent core drill, electric, 2.5 H.P. 1" to 8" bit diameter, includes hourly operating cost	retro	demo	ea.	2	2	2	2	8	8	12	12	24	24	40	40
Rent mixer power mortar & concrete gas 6 CF, 18 HP, one day including 4 hours operating cost	retro	demo	Ea.									2	2	2	2
Rent backhoe-loader 40 to 45 HP 5/8 CY capacity, one day including 4 hours operating cost	retro	demo	per day	1	1	1	1	1	1	1	1	1	1	1	1
Rent, asphalt distributor, trailer mounted, 38 HP diesel 2000 gallon, one day including 4 hours operating cost	retro	pave	ea.	1	1	1	1	1	1	1	1				
Mobilization or demobilization, dozer, loader, backhoe or excavator, 70 H.P. to 150 H.P., up to 50 miles	retro	demo	per job	4	4	4	4	4	4	4	4	2	2	2	2
Demolish, remove pavement & curb, curbs, excludes hauling, minimum labor/equipment charge	retro	demo	Job	1	1	1	1	1	1	1	1				
Selective demolition, rubbish handling, dumpster, 6 C.Y., 2 ton capacity, weekly rental, includes one dump per week, cost to be added to demolition cost.	retro	demo	Week	2	2	3	3	10	10	18	18	4	4	6	6
Deconstruction of concrete, floors, concrete slab on grade, plain, 4" thick, up to 2 stories, excludes handling, packaging or disposal costs	retro	demo	S.F.	4	4	6	6	9	9	15	15	24	24	40	40
Selective concrete demolition, reinforce less than 1% of cross-sectional area, break up into small pieces, excludes shoring, bracing, saw or torch cutting, loading, hauling, dumping	retro	demo	C.Y.	1	1	2	2	3	3	5	5	8	8	13	13

Table 15. Task Descriptions and Quantities

Task Description	Construc-tion Type	Work Type	Unit	Small Retail/Commercial				Medium Office/School				Large Office/Retail/Hospital			
				6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving
				Quantity for Each Scenario											
Selective concrete demolition, minimum labor/equipment charge	retro	demo	Job					1	1	1	1	1	1	1	1
Concrete sawing, concrete slabs, rod reinforced, up to 3" deep	retro	demo	L.F.	82	82	113	113	364	364	691	691	24	24	40	40
Concrete sawing, concrete, existing slab, rod reinforced, for each additional inch of depth over 3"	retro	demo	L.F.	82	82	113	113	364	364	691	691	24	24	40	40
Selective demolition, concrete slab cutting/sawing, minimum labor/equipment charge	retro	demo	Job	1	1	1	1	1	1	1	1	1	1	1	1
Concrete core drilling, core, reinforced concrete slab, 2" diameter, up to 6" thick slab, includes bit, layout and set up	retro	demo	Ea.									24	24	40	40
Add equipment minimum for concrete demo- assume labor minimum subsumed under saw cut minimum	retro	demo	per job	1	1	1	1	1	1	1	1	1	1	1	1
Wire, copper, stranded, 600 volt, 250 kcmil, type THWN-THHN, normal installation conditions in wireway, conduit, cable tray	new	panel	C.L.F.					0	0						
Wire, copper, stranded, 600 volt, 300 kcmil, type THWN-THHN, normal installation conditions in wireway, conduit, cable tray	retro	panel	C.L.F.					1	1						
Wire, copper, stranded, 600 volt, 600 kcmil, type THWN-THHN, normal installation conditions in wireway, conduit, cable tray	new	panel	C.L.F.								1	0	0	0	1
Wire, copper, stranded, 600 volt, 600 kcmil, type THWN-THHN, normal installation conditions in wireway, conduit, cable tray	retro	panel	C.L.F.							0.5	0.5	0.3	0.3	2.11	2.11
Outlet boxes, pressed steel, 4" square	retro	electric	Ea.	4	4	6	6	9	9	15	15	24	24	40	40
Outlet boxes, pressed steel, 4" square	new	electric	Ea.	4	4	6	6	9	9	15	15	24	24	40	40

Table 15. Task Descriptions and Quantities

Task Description	Construction Type	Work Type	Unit	Small Retail/Commercial				Medium Office/School				Large Office/Retail/Hospital			
				6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving
				Quantity for Each Scenario											
Outlet boxes, pressed steel, covers, blank, 4" square	retro	electric	Ea.	4	4	6	6	9	9	15	15	24	24	40	40
Outlet boxes, pressed steel, covers, blank, 4" square	new	electric	Ea.	4	4	6	6	9	9	15	15	24	24	40	40
permitting & inspection, 4 internal and 2 external circuits, excludes general building permit fees	new	fee	per job	1	1	1	1		1	1					
permitting & inspection, 14 internal and 7 external circuits, excludes general building permit fees	new	fee	per job								1				
permitting & inspection, 14 internal circuits, excludes general building permit fees	new	fee	per job									1	1	1	1
permitting, per internal circuit over 4, excluding general building permit fees	new	fee	per circuit					1		9		9	9	26	26
permitting & inspection, 4 internal and 2 external circuits, excludes general building permit fees	retro	fee	per job	1	1	1	1	1	1						
permitting & inspection, 14 internal and 7 external circuits, excludes general building permit fees	retro	fee	per job							0.75	0.75				
permitting & inspection, 14 internal circuits, excludes general building permit fees	retro	fee	per job									1	1	1	1
permitting, per internal circuit over 4, excluding general building permit fees	retro	fee	per circuit									9.0	9.0	26.0	26.0
Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 100 amp, 12 circuits, includes 20 A 1 pole plug-in breakers (additional to existing)	retro	panel	Ea.	1	1										

Table 15. Task Descriptions and Quantities

Task Description	Construction Type	Work Type	Unit	Small Retail/Commercial				Medium Office/School				Large Office/Retail/Hospital			
				6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving
				Quantity for Each Scenario											
Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 100 amp, 12 circuits, includes 20 A 1 pole plug-in breakers (cost avoided by installing 200 amp panel at time of new construction)	new	panel	Ea.	1	1										
Load centers, 1 phase, 3 wire, main lugs, indoor, 120/240 V, 200 amp, 16 circuits, includes 20 A 1 pole plug-in breakers	both	panel	Ea.			1	1								
C.I.P. concrete forms, slab on grade, edge, wood, 7" to 12" high, 4 use, includes erecting, bracing, stripping and cleaning	retro	pave	SFCA	16	16	32	32	36	36	60	60	96	96	160	160
Reinforcing steel, in place, dowels, smooth, 12" long, 1/4" or 3/8" diameter, A615, grade 60	retro	pave	Ea.	12	12	24	24	27	27	45	45	72	72	120	120
Structural concrete, in place, slab on grade (3000 psi), 4" thick, includes concrete (Portland cement Type I), placing and textured finish, excludes forms and reinforcing	retro	pave	S.F.	4.0	4.0	8.0	8.0	9.0	9.0	15.0	15.0	24	24	40	40
Structural concrete, in place, minimum labor/equipment charge	retro	pave	Job	1	1	1	1	1	1	1	1	1	1	1	1
Asphaltic concrete paving, parking lots & driveways, 6" stone base, 2" binder course, 2" topping, no asphalt hauling included	retro	pave	S.F.	123	123	170	170	546	546	1036	1036				
Intermediate metal conduit, 1" diameter, to 15' high, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	retro	race	L.F.	78	78	94	94	182	182	345	345	1133	1133	1551	1551
Electric metallic tubing (EMT), 1" diameter, to 10' high, incl 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	new	race	L.F.										655		1269

Table 15. Task Descriptions and Quantities

Task Description	Construc-tion Type	Work Type	Unit	Small Retail/Commercial				Medium Office/School				Large Office/Retail/Hospital			
				6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving	6% - Repaving	6% - No Repaving	10% - Repaving	10% - No Repaving
				Quantity for Each Scenario											
Electric metallic tubing (EMT), 1-1/2" diameter, to 10' high, incl 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	new	race	L.F.					25	25						
Electric metallic tubing (EMT), 1-1/2" diameter, to 10' high, incl 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	retro	race	L.F.						50						
Electric metallic tubing (EMT), 2" diameter, to 10' high, incl 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	new	race	L.F.							31	109	10	15	13	106
Electric metallic tubing (EMT), 2" diameter, to 10' high, incl 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	retro	race	L.F.							50	50	30	30	211	211
PVC conduit, schedule 40, 1" diameter, to 10' H, incl terminations, fittings, & support	new	race	L.F.									331		578	
Excavating, chain trencher, utility trench, common earth, includes excavation and backfill, minimum labor/equipment charge	retro	trench	Job	1	1	1	1	1	1	1	1				
architectural plans/drawings	retro	fee	per hour	4	4	8	8	10	10	15	15	18	18	30	30
architectural plans/drawings	new	fee	per hour	2	2	3	3	3	3	4	4	6	6	9	9
site and load study	retro	fee	per $1000					2	2	2	2	4	4	5	5
Excavating, chain trencher, utility trench, common earth, 40 H.P., 16" wide, 24" deep, operator riding, includes backfill	new	trench	L.F.	49	156	85	156	186	126	383	253				

Table 15. Task Descriptions and Quantities

Task Description	Construction Type	Work Type	Unit	Small Retail/Commercial: 6% - Repaving	Small Retail/Commercial: 6% - No Repaving	Small Retail/Commercial: 10% - Repaving	Small Retail/Commercial: 10% - No Repaving	Medium Office/School: 6% - Repaving	Medium Office/School: 6% - No Repaving	Medium Office/School: 10% - Repaving	Medium Office/School: 10% - No Repaving	Large Office/Retail/Hospital: 6% - Repaving	Large Office/Retail/Hospital: 6% - No Repaving	Large Office/Retail/Hospital: 10% - Repaving	Large Office/Retail/Hospital: 10% - No Repaving
				Quantity for Each Scenario											
Excavating, chain trencher, utility trench, common earth, 40 H.P., 16" wide, 24" deep, operator riding, includes backfill	retro	trench	L.F.	61	61	85	85	273	273	518	518				
Intermediate metal conduit, 1" diameter, to 15' high, includes 2 terminations, 2 elbows, 11 beam clamps, and 11 couplings per 100 LF	new	race	L.F.	52	110	58	115	124	450	255	465				
Mobilization or demobilization, dozer, loader, backhoe or excavator, 70 H.P. to 150 H.P., up to 50 miles	retro	trench	per job	1	1	1	1	1	1	1	1				
Circuit breakers, bolt-on, 10 k A I.C., 1 pole, 120-volt, 15-50 amp	new	panel	Ea.					9	9	15	15	24	24	40	40
Circuit breakers, bolt-on, 10 k A I.C., 1 pole, 120 volt, 15-50 amp	retro	panel	Ea.					9	9	15	15	24	24	40	40
panelboard, main breaker, 120/208V, no circuit breakers, 225 amp	new	panel	Ea.					1	1						
panelboard, main breaker, 120/208V, no circuit breakers, 225 amp	retro	panel	Ea.					1	1						

Appendix D: EV Capable Installation Configurations

This section includes figures to generally depict the configuration of each scenario that was analyzed in the cost model. They are not intended to include all details of a particular installation nor are they intended to represent any specific installation. The figures assume all parking spaces to be 9 feet wide by 18 feet long,[45] but the authors recognize that many non-EV parking spaces will likely be smaller than that. These diagrams are also not intended to show or account for compliance with accessibility requirements, other than some space being accounted for in the overall parking area dimensions to eventually account for car and van accessible spaces.

[45] This is the minimum size required for EV parking spaces as specified in Title 24, Part 11, Section 4.106.4.2.2.

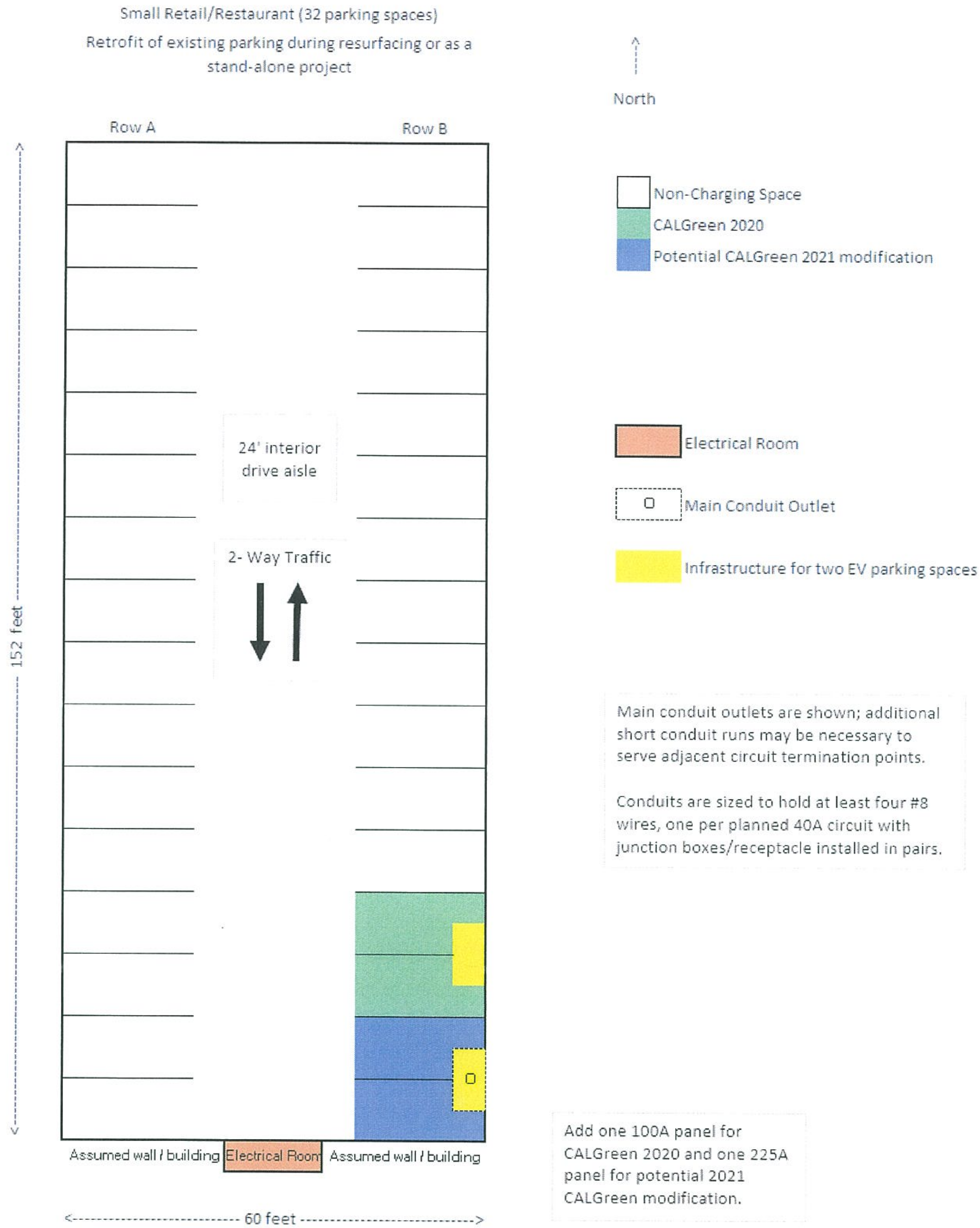

Figure 4. Retrofit scenario of small retail/restaurant parking area with 32 parking spaces

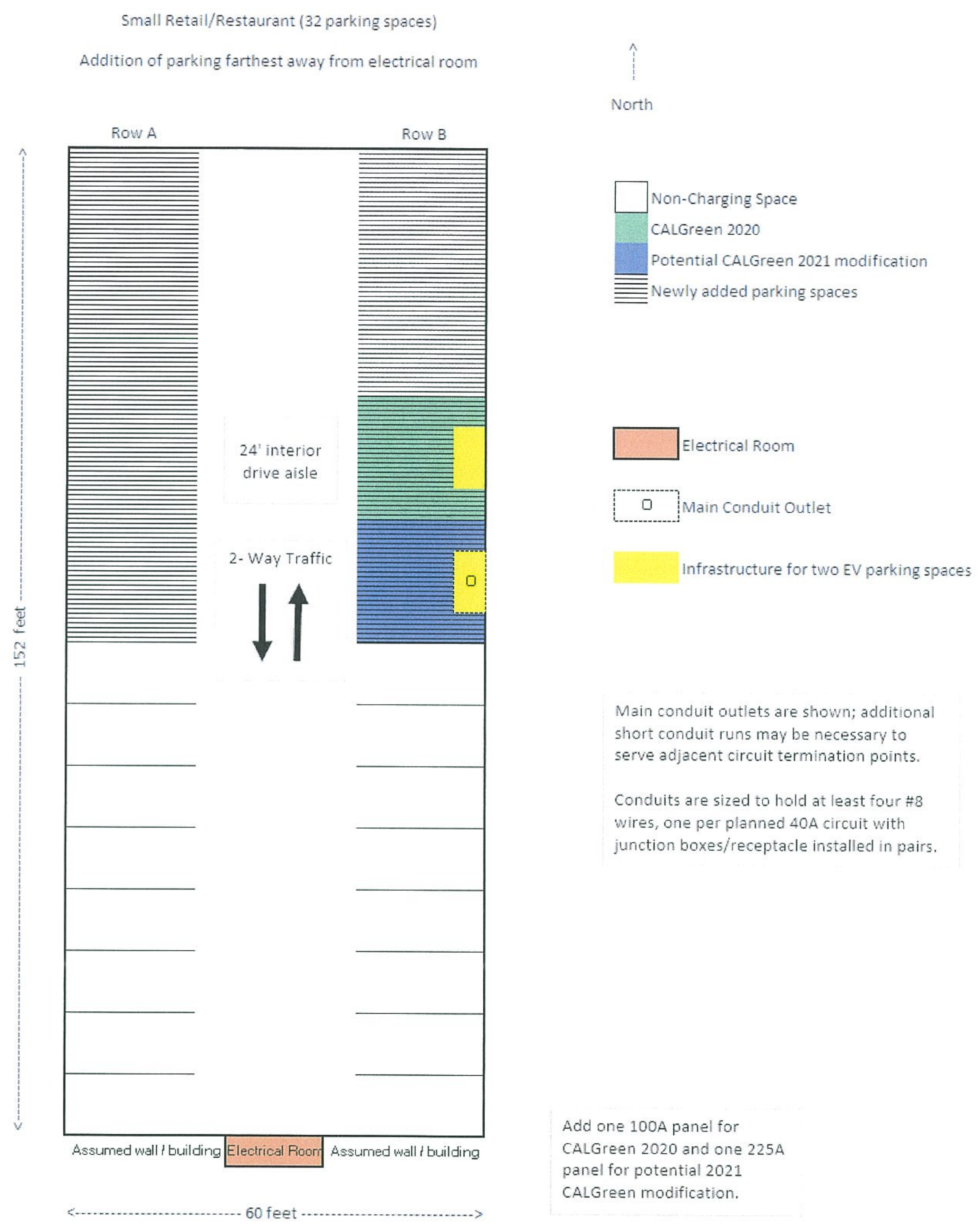

Figure 5. Parking addition scenario of small retail/restaurant with 32 parking spaces

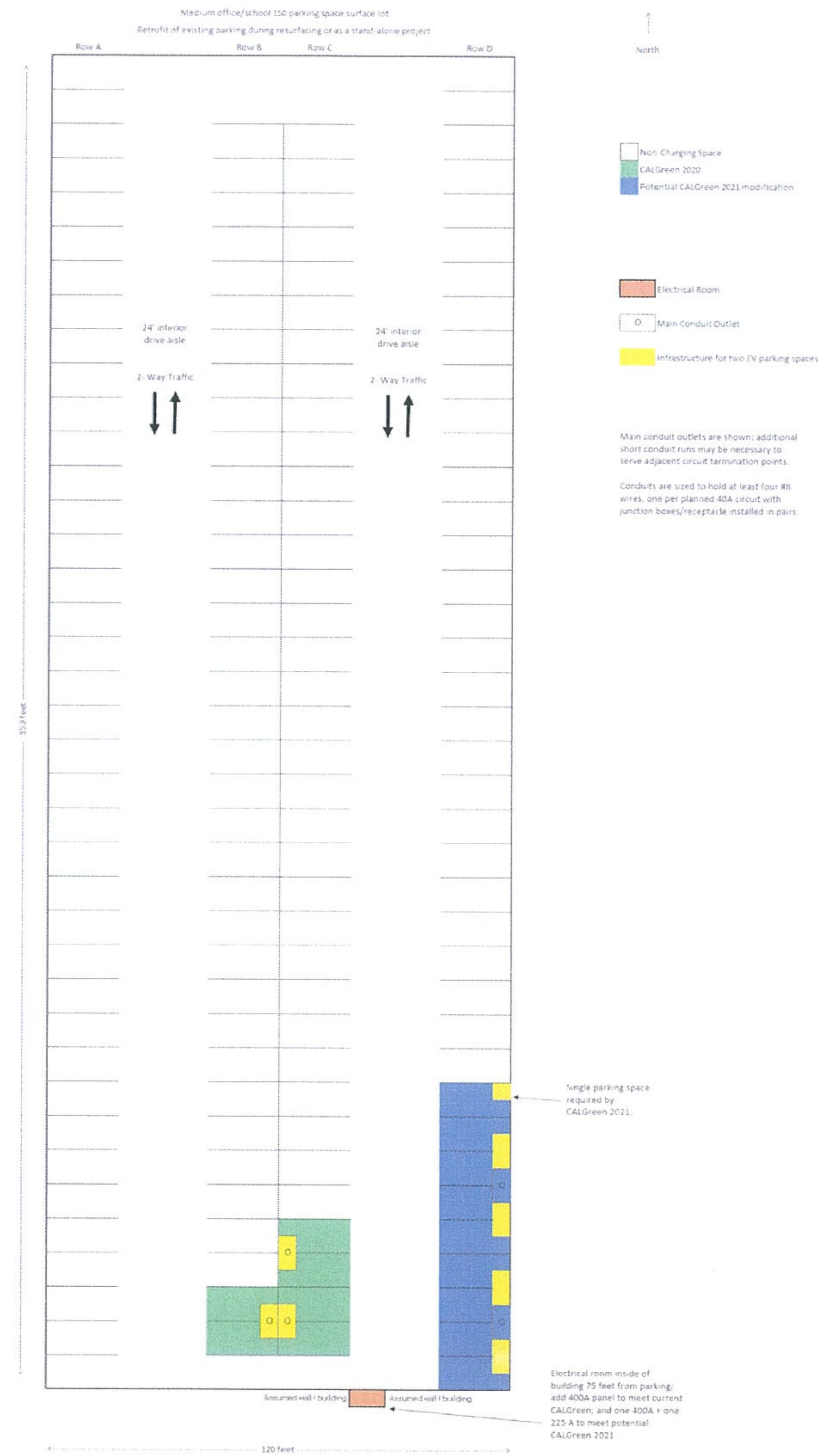

Figure 6. Retrofit scenario of medium office/school with 150 parking spaces

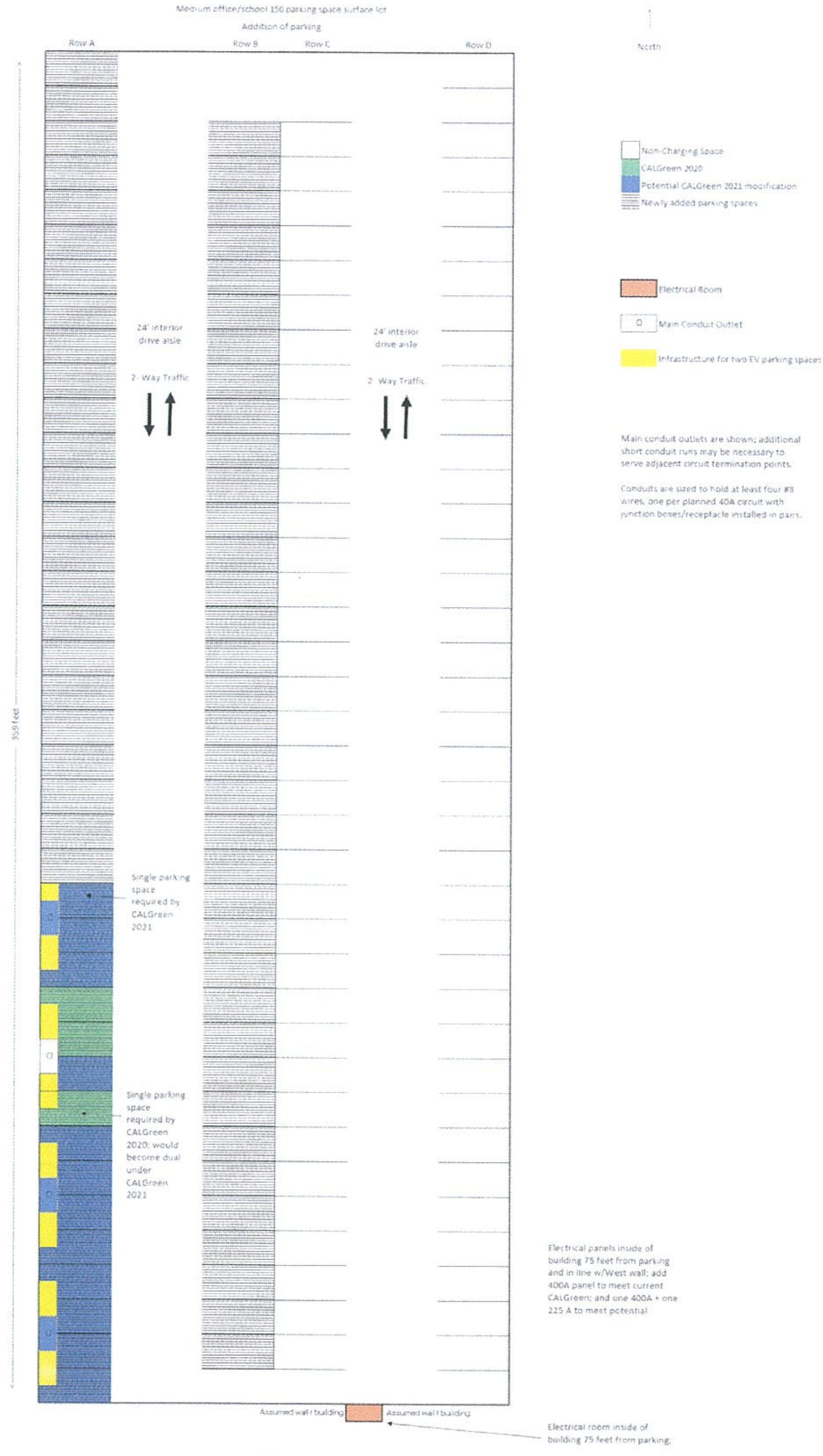

Figure 7. Parking addition scenario of medium office/school with 150 parking spaces

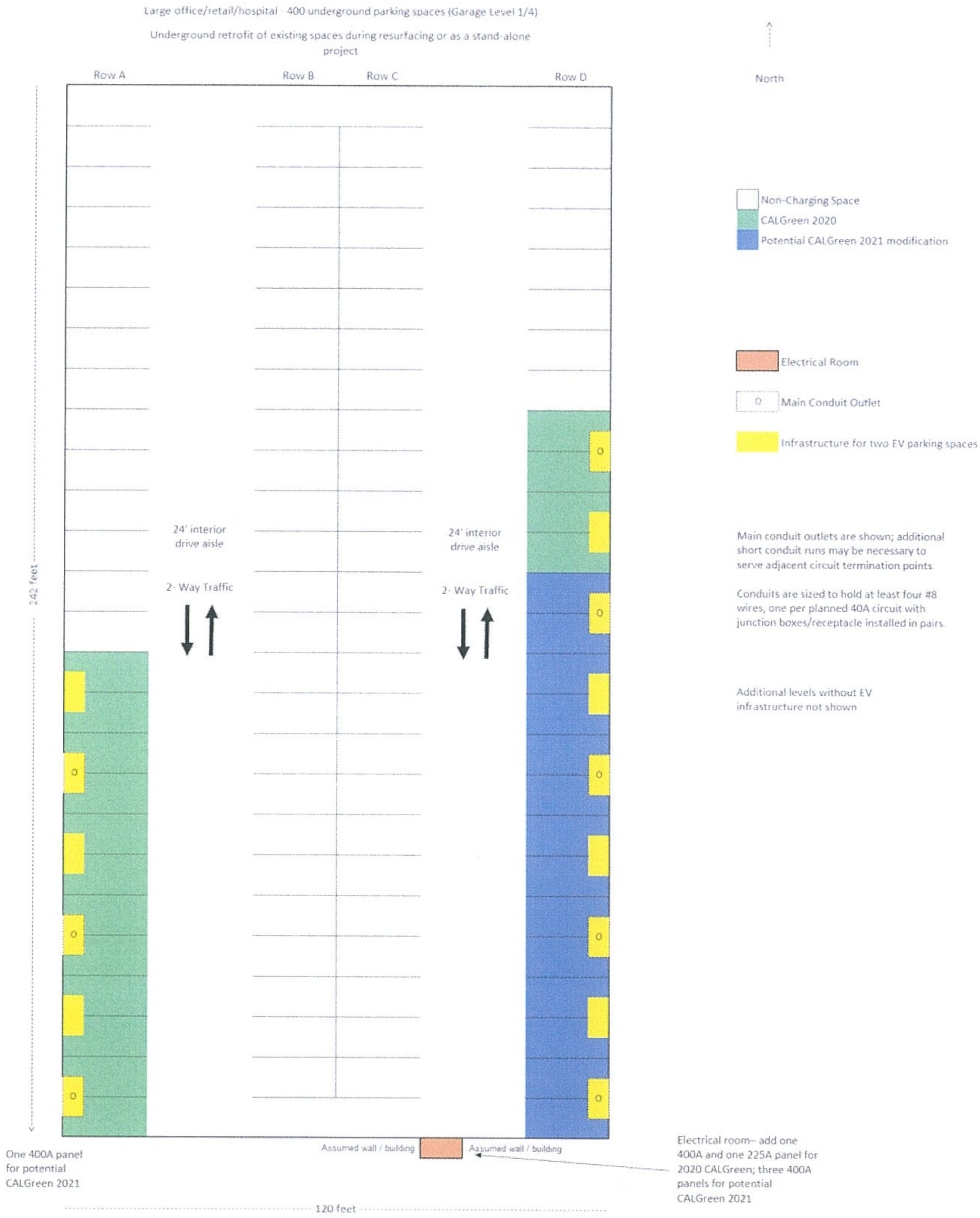

Figure 8. Retrofit scenario of large office/retail/hospital with 400 parking spaces (Level 1/4)

Figure 9. Retrofit scenario of large office/retail/hospital with 400 parking spaces (Level 2/4)

Figure 10. Repaving scenario of large office/retail/hospital with 400 parking spaces (Level 1/4)

Figure 11. Repaving scenario of large office/retail/hospital with 400 parking spaces (Level 2/4)